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FISCAL YEAR 1990 DEPARTMENT OF ENERGY AUTHORIZATION

(Solar and Renewable Energy and Energy Conservation)

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS

FIRST SESSION

FEBRUARY 28; MARCH 2, 1989

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1990 DEPARTMENT OF ENERGY AUTHORIZATION

TUESDAY, FEBRUARY 28, 1989

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Energy Research and Development,
Washington, DC.

The Subcommittee met at 1:31 p.m., in Room 2318, Rayburn House Office Building, Hon. Marilyn Lloyd, Chairman of the Subcommittee, presiding.

Present: Representatives Lloyd, Morrison, Fawell, Smith and Wolpe.

OPENING STATEMENT OF HON. MARILYN LLOYD, CHAIRMAN, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Mrs. Lloyd (presiding). The Subcommittee will come to order.

Good afternoon, ladies and gentlemen. Our hearing today will focus on the Department of Energy's FY-1990 budget submission for Energy Conservation, Research and Development in Solar and Other Renewables.

The Conservation Research and Development program within the Subcommittee's jurisdiction includes buildings and community systems, industrial and most of the multi-sector activities, including the energy conversion and utilization technologies.

The budget submission for these activities is only $58.2 million, a reduction of 52 percent from FY-1989 appropriated levels of $105.1 million.

The renewable energy activities within our Subcommittee includes Solar Buildings, Solar thermal, Photovoltaics, Biofuels, Wind and Ocean Energy and authorization for the Solar Energy Research Institute, SERI.

Also included in the renewables category are Geothermal Energy, and Electric Energy Systems and Energy Storage Systems.

The budget submission for these programs is $109 million, a reduction of $37.5 million from Fiscal 1989 appropriated levels of $146.5 million. This is a 26 percent decrease.

The very low request for these programs follows a pattern of recent years by the Department of Energy of attempting to severely reduce the amount of government funding available for these activities.

We are all aware of our budget problems and the difficult decisions regarding allocation of our scarce resources. However, I believe that we must try to provide a more consistent research climate for the activities, even if it must be at a lower level than we would prefer.

Our first witness today is the Honorable John R. Berg, the Assistant Secretary for Conservation and Renewable Energy at the Department of Energy. Dr. Berg will present and discuss the Department's FY 1990 submission for both Conservation and Renewable activities.

And following Dr. Berg's statement and our panel's questions, we will receive testimony from our non-DOE witnesses regarding energy conservation programs.

Before I begin, I would like to recognize my friend and colleague, the Honorable Sid Morrison, ranking Republican Member, for his opening statement.

OPENING STATEMENT OF HON. SID MORRISON, RANKING REPUBLICAN, SUBCOMMITTEE ON ENERGY, RESEARCH AND DEVELOPMENT

Mr. MORRISON. Madam Chairman, thank you. I do have a formal statement and I think, in the interest of time, I will ask that it be inserted in the record and look forward to the hearing today on Conservation and Renewable Energy.

Thank you.

Mrs. LLOYD. Thank you. Without objection, your complete statement will be made a part of the record.

[The prepared opening statement of Mr. Morrison follows:]

HON. SID MORRISON (R-WA)
OPENING STATEMENT
FY 1990 DOE AUTHORIZATION HEARING ON CONSERVATION AND SOLAR AND RENEWABLE ENERGY R&D

FEBRUARY 28, 1989

GOOD AFTERNOON. I AM DELIGHTED TO BE HERE AS THE SUBCOMMITTEE BEGINS OUR FIRST HEARING ON CONSERVATION AND RENEWABLE ENERGY R&D TODAY.

I APPRECIATE THE EFFORT DOE HAS MADE OVER THE LAST YEAR TO IMPLEMENT THE GOALS SET FORTH IN BOTH ENERGY CONSERVATION AND RENEWABLE ENERGY R&D PROGRAMS. THE DEPARTMENT HAS PURSUED COOPERATIVE RESEARCH PROJECTS AND COST-SHARING WITH INDUSTRIES, AND SUPPORTED THE THREE COLLABORATIVE PILOT CENTERS FOR HIGH TEMPERATURE SUPERCONDUCTIVITY. WITH LEADERSHIP FROM DOE, THE COMMITTEE ON RENEWABLE ENERGY COMMERCE AND TRADE HAS ALSO MADE SOME GOOD PROGRESS OVER THE LAST COUPLE OF YEARS TO ACCELERATE THE ACCEPTANCE AND COMPETITIVENESS OF RENEWABLE ENERGY TECHNOLOGIES IN THE MARKETPLACE.

IN THE FISCAL 1990 BUDGET REQUEST PRESENTED TO US, I SEE THE ADMINISTRATION STATED THAT THE BUDGET REPRESENTS A SIGNIFICANT COMMITMENT TO DEVELOP PROMISING RENEWABLE ENERGY TECHNOLOGIES AND SUPPORT HIGHEST PRIORITY ACTIVITIES IN ENERGY CONSERVATION. I AM NOT SURE HOW DOE CAN FULFILL THIS COMMITMENT WHEN THE BUDGET REPRESENTS A SIGNIFICANT REDUCTION FROM THE APPROPRIATED

LEVEL FOR THE CURRENT YEAR. I WELCOME THE NEW ASSISTANT SECRETARY, JOHN BERG, AND YOUR WORDS OF WISDOM THIS AFTERNOON.

AS I REVIEWED THE VARIOUS R&D AREAS UNDER CONSERVATION AND RENEWABLE ENERGIES, I FOUND THAT SEVERAL PROGRAMS SUCH AS HIGH TEMPERATURE SUPERCONDUCTIVITY AND SUPERCONDUCTING MAGNETIC ENERGY STORAGE HAVE A BROAD RANGE OF INTEREST FROM BOTH CIVILIAN AND DEFENSE PERSPECTIVES. I THINK IT IS VERY IMPORTANT TO DEVELOP GOOD COMMUNICATION AMONG ALL PARTIES INVOLVED TO SHARE KNOWLEDGE, OR EVEN COST, OF THESE PROGRAMS.

AS WE ENTER THE 101ST CONGRESS, AN IMPORTANT ITEM ON OUR AGENDA WILL BE THE

MITIGATION OF ACID RAIN AND THE SO-CALLED GREENHOUSE EFFECT. CONSERVATION AND RENEWABLE ENERGIES CAN PLAY A SIGNIFICANT ROLE IN THIS. I AM ALSO PLEASED THAT DOE IS PREPARING A DOCUMENT TO PROVIDE INFORMATION ON EMISSIONS FROM VARIOUS ELECTRIC GENERATION SYSTEMS, INCLUDING CONVENTIONAL AND ADVANCED ELECTRIC PLANTS. I THINK THIS WOULD HELP SET R&D PRIORITIES IN THE POWER GENERATION ARENA.

I LOOK FORWARD TO THE TESTIMONY FROM OUR DISTINGUISHED WITNESSES TODAY.

Mrs. **Lloyd.** Dr. Berg, we are delighted to have you with us today.

Would you identify your associates?

Dr. **Berg.** Thank you very much, Madam Chairman. I have a statement which I believe has been submitted for the record.

Mrs. **Lloyd.** Without objection, all of our witnesses' entire statements will be made a part of the record. And you may summarize and proceed as you wish.

STATEMENT OF DR. JOHN R. BERG, ASSISTANT SECRETARY, CONSERVATION AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY, ACCOMPANIED BY AL STREB, DEPUTY ASSISTANT SECRETARY FOR CONSERVATION, OFFICE OF CONSERVATION AND RENEWABLE ENERGY; DR. ROBERT SAN MARTIN, DEPUTY ASSISTANT SECRETARY FOR RENEWABLE ENERGY, OFFICE OF CONSERVATION AND RENEWABLE ENERGY; AND FRANK STEWART, JR., DIRECTOR OF THE STATE AND LOCAL ASSISTANCE PROGRAMS, OFFICE OF CONSERVATION AND RENEWABLE ENERGY

Dr. **Berg.** I am accompanied by Mr. Al Streb on my right, who is the Deputy Assistant Secretary for Conservation, the Deputy Assistant Secretary for Renewable Energy, Dr. Robert San Martin on my immediate left and to his left is the Director of the State and Local Assistance Programs, Mr. Frank Stewart.

We appreciate this opportunity to appear before you today to provide information on the fiscal year 1990 budget request for the Department's Conservation and Renewable Energy Programs.

The budget for these programs is consistent with and supports the goals and objectives of the National Energy Policy and is fully responsive to the Administration and Congressional goals of deficit reductions.

We have requested, as you have mentioned, $112.5 million for the Renewable Energy Technology programs, $54.6 million for the Energy Conservation, Research and Development, and $7.6 million for the Office of State and Local Assistance Programs.

The budget was developed based on our multi-year program plans for each of the Conservation and Renewable Energy Programs.

The approach we used was to set goals for each program and to carefully develop the strategy to accomplish those goals.

Industry is consulted to determine their needs and priorities. In general, the goals for the Conservation and Renewable Energy Programs are to contribute to the technical and economic environment necessary to support the development of energy conservation and renewable technologies.

To accomplish this goal, the multi-year plans provide for prioritization of our research needs.

In the area of our State and Local Assistance Programs, the monies are requested for program management, for management of appropriated funds for State grants and also for monitoring the States' use of the oil over charge monies.

Now, admittedly the budget request to implement these plans is not a generous one, but it is sufficient and is within the current Federal budget limitations.

We concentrated our efforts on the highest priority research to address the most significant and critical technological issues. We believe this will provide an effective program that will accomplish our program goals.

We also continue to focus on improved planning and dissemination of the results of our R&D programs and our expanding collaboration with the use of the private sector in the forms of cost-sharing and technology transfer.

The research sponsored by the Federal Government and private companies is now bearing fruit in better materials and improved components and systems, designs which will increase energy use efficiencies and make alternative fuel use both reliable and economically attractive.

I would like to mention for a moment a few of the major accomplishments achieved during the past, 1988, year.

In our area of photovoltaics continues to bear fruit. We set four world records this year, a 13.3 percent energy conversion on laboratory amorphous silicon cells by ECD of Troy, Michigan; a 6.7 energy conversion of a three-foot square amorphous silicon module set by Chronar in Princeton, New Jersey; a 14.6 energy conversion record on a laboratory multi-junction cell made up of amorphous silicon on copper indium diselenide set by ARCO-Solar of Camarillo, California.

And, finally, a 31 percent energy conversion on a lab multi-junction cell of gallium arsenide and silicon made by Sandia Varian and Stanford University. The United States is now the world leader in amorphous silicon film technology.

In our area of biomass, a biomassgasifer concept developed at SERI is now being scaled up and built by SynGas on Long Island, New York. This industry facility will be a 10 megawatt wood-to-electricity facility.

Another instance, based on the results of our DOE cost-shared research, Scott Paper Company, using its own money, planted 400 acres of short rotation forestry near its Mobile, Alabama facility in 1988. The wood is being used to produce electricity at Scott's paper and pulp products complex in Mobile, in the future.

The Department established three high-temperature super-conductivity pilot centers this year at Argonne, Los Alamos and Oak Ridge National Laboratories. They are to work cooperatively with industry to develop enabling technologies for high-temperature superconducting commercialization.

That is an exciting and a very fast-moving development in a very competitive area. And so far we have four industrial contracts signed, 13 more very near execution and 30 others in serious discussion between the three laboratories.

In the area of combustion research, the capability for a non-intrusive look into a production engine, internal combustion engine while it is running, was developed at Sandia, Livermore, in which a fiber-optic is inserted into a spark plug and is able to watch the propagation and ignition of the fuel vapor in the production engine.

That particular spark plug is being marketed by Barrack Technology Corp. is and called the "Barrack-Witze" spark plug. They are located in Massachusetts, by the way.

Our energy-related inventions program continues to provide assistance to inventors. One of our inventors this year developed a new design for precision bearings. This potential breakthrough could have wide-ranging applications from submersible pumps to computer printers. The bearings could be produced domestically at a fraction of the cost of imports.

In our industrial program, in a joint project with the Solar Energy Research Institute, we have successfully continued in a process of extracting the phenolic-rich oil fraction from bark and wood sawdust waste.

This material will be useful to form an adhesive precursor which will be used to make plywood. Adhesives from wood waste thus could displace present adhesives derived from petroleum used in the plywood industry.

These resins are being tested by Weyerhaeuser, Boise Cascade, Georgia Pacific and other interested end users as well as producers of acid resins.

In our Industrial Programs, we are also working with Allied Signal on a cost-sharing basis. They have developed a membrane system that provides alternatives to existing energy-intensive distillation and other processes for the separation of petrochemical streams. A cost-shared fuel test at an Exxon facility has continuously and successfully separated hydrogen sulfide and carbon dioxide from natural gas.

Because of the suspected adverse environmental effects of conventional CFC materials used in cooling and insulation applications, the Department is investigating possible substitutes. Oak Ridge National Laboratory has identified several promising refrigerant mixtures that have not been identified by other researchers and, in fact, they are testing those materials along with industrial substitutes from Dupont and others.

In our Transportation Program, the first phase of a design procurement for the ceramic components for gas turbines has been completed through collaborative efforts with the ceramic industry.

These components, when developed, will enable operation of small turbine engines at temperatures in excess of 2,500 degrees Farenheit, thereby producing potential energy improvements of more than 30 percent over today's engines.

Madam Chairman, these are just some of the accomplishments that have resulted from research sponsored by the Federal Government and the private sector.

We must continue to look to the future and pursue those activities which will expand and improve our energy use options.

The long-term solution to our energy problem is through improved technology. We must improve both the utilization efficiency and the capability to use alternative fuels. And the only way to improve technology is through research. It is in this area of research that we think there are some crucial decisions to be made, and this is where the Congress and the Department of Energy need to work together. Together, we need to be assured that every dollar appropriated for our research and development programs is spent productively.

If we're going to spend more than the President requests, then we should maintain the course which the Conservation Program with input from industry and academia, and the renewable program, with the input from their peer reviews, are now following and continue to support justified work that advances the National Energy Environmental and Security interests.

Overall, this will contribute to our U.S. productivity and competitiveness. If we do that, we could turn the budget reductions that we face into an opportunity to bring more discipline and higher quality work to our research programs in the most cost-efficient manner and most cost-effective way.

It is important that the decisions be made to truly move the Nation toward greater energy efficiency and broader availability of supply options.

Madam Chairman, we appreciate this opportunity to appear before you today and gain your advice on these matters.

We look forward to answering questions that you and the Subcommittee may have.

Thank you.

[The prepared statement of Dr. Berg follows:]

STATEMENT OF

DR. JOHN R. BERG

ASSISTANT SECRETARY FOR CONSERVATION AND RENEWABLE ENERGY

U.S. DEPARTMENT OF ENERGY

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

U. S. HOUSE OF REPRESENTATIVES

FEBRUARY 28, 1989

Madam Chairman and Members of the Subcommittee, I appreciate the opportunity to appear before you today to provide information on the FY 1990 budget request concerning the Department's Conservation, State and Local Assistance, and Renewable Energy programs. The budget for these programs is consistent with the goals and objectives of national energy policy and is fully responsive to the Administration and Congressional goals of deficit reduction.

I would now like to discuss each of our major program areas under your jurisdiction and its related FY 1990 funding request.

BUDGET REQUEST FOR ENERGY CONSERVATION R&D

The FY 1990 budget request for energy conservation research and development totals $54.6 million. It includes $12.0 million for Buildings and Community Systems, $16.1 million for Industrial Programs and $24.1 million for Multi-Sector programs and $2.4 million for Policy and Management.

BUILDINGS AND COMMUNITY SYSTEMS

We are requesting $12.0 million for Buildings and Community Systems (BCS) research, technology transfer, and regulatory activities in FY 1990. The funds requested include $7.8 million for research and development projects, $1.0 million for technology assessment and transfer, $2.5 million for program direction, and $0.7 million for capital equipment. The R&D activities focus on selected high-risk and high-payoff projects, which are not likely to be pursued by the private sector alone. Many are carried out by private companies and institutions operating under cost-shared contracts or cooperative agreements with the Department. Our activities complement industry efforts and do not displace them.

Despite impressive gains in energy efficiency during the past 15 years, the buildings sector still uses almost 28 quads of energy annually. This is 36 percent of our total national consumption, more than either the transportation or industrial sector. This energy use is forecasted to increase to 40 quads by 2010. This estimate was provided by the Energy Information Administration and is based on energy supplier data. In residential buildings, space heating, water heating, and refrigeration use the largest amounts of energy; in commercial buildings, space heating, lighting, and air conditioning use the largest amounts. It is estimated that a 30% reduction from present levels of energy use could be achieved by building envelope improvements that reduce heating, ventilating, air-conditioning, and lighting loads and that significant additional savings could be achieved by improving the efficiency of equipment used to perform these and related building functions. Our target is to help to hold building energy use in 2010 to 28 quads - a savings of 12 quads from presently forecasted levels. The Buildings and Community Systems program conducts research to advance the technologies that can produce these savings and makes the results of that research available to the private sector. This program also implements building energy regulatory activities mandated by Congress.

The research and development funds are for three subprograms: Building Systems, Community Systems, and Technology and Consumer Products. We are requesting $3.5 million for the Building Systems subprogram to continue research on the building envelope including materials, fenestration, roofs, walls, and foundations; indoor air quality, infiltration, and ventilation; advanced commercial building subsystems interactions; building performance simulation; and energy retrofit of existing buildings.

Our building materials research will continue development of vapor and air barriers and thermal performance testing. Our fenestration research includes development, in cooperation with Canada and ASHRAE, of procedures for evaluating the complex windows that industry is beginning to produce.

Our roof research focuses on improving the energy performance and durability of roofs. In FY 1990, we will continue to operate the Roof Research Center as a DOE user facility with industry participation. Research areas will include study of membrane aging and moisture effects. We will complete our projects for testing light weight concrete, sprayed foam, and ceramic paint products. We will complete the guidebook on low slope roofs and publish guidelines on using roof mass to improve thermal performance.

In the area of walls and foundations research, we will complete some important new design tools which pull together the results of research at DOE and other organizations. These include a builder's version of the Building Foundations Design Handbook and a handbook on mitigation of moisture problems in energy efficient houses.

In FY 1990, we will develop a protocol for indoor air quality measurement and diagnosis, will continue to evaluate energy efficient ventilation technologies, and will continue participation in collaborative efforts to secure voluntary participation in industry consensus standards for indoor air quality, infiltration, and ventilation.

In the area of building subsystems interactions, we will produce and test a computer program for building designs and will continue to maintain and update the DOE-2 building energy performance simulation.

In the existing buildings activity we will monitor projects selected in the FY 1989 solicitation of retrofit technologies for single family, multifamily, and commercial buildings, and analyze the results.

We are requesting $0.5 million for the Community Systems subprogram. These funds will be used to conduct laboratory testing of the additives to reduce the friction of fluids used in district cooling and to initiate full scale testing of promising additives.

We are requesting $3.8 million for the Technology and Consumer Products subprogram in FY 1990. The purpose of this research is to provide technologies that could lead to more efficient building energy conversion processes and equipment. The greatest promise for significant energy savings in building equipment is in heating, cooling, and lighting--areas that account for 60% of the energy used in buildings. Our work on improved efficiency in those areas focuses on thermally activated heat pumps, advanced refrigeration, and advanced lighting.

In thermally activated heat pumps, we will complete laboratory testing and evaluation of a prototype residential-size absorption heat pump and will design, fabricate, and test critical components for an engineering unit for field testing. We will also continue development of key components for an internal combustion engine-driven heat pump and for a magnetically coupled free piston Stirling engine-driven compressor.

In the area of combustion systems, we will continue research on new oil atomization processes to achieve more complete combustion, reduce emissions, and enhance heat transfer.

In advanced refrigeration systems, we will continue laboratory breadboard testing of refrigerant mixtures in advanced cycle configurations. We will also continue research to determine engineering properties of novel refrigerant mixtures.

In lighting equipment research, we will continue to investigate surface wave lamp phenomena, and inductive driving techniques for electrodeless high intensity discharge (HID) lamps. We will complete our long term tests of isotopically enriched mercury lamps.

The goal of the Tecnnology Assessment and Transfer subprogram is to provide the analytic tools and information needed for program planning and to ensure that research results and information on conservation in buildings are transferred to potential users. We are requesting $1.0 million for this subprogram. This funding will continue support for centralized BCS technology transfer activities, for technology assessments and program planning, for studies of building conservation technologies in other developed countries and for assessments of their impact on U.S. trade and technology leadership.

We are requesting $0.7 million to provide capital equipment needed to support those Buildings and Community Systems research efforts conducted by the national laboratories and universities. In addition, we are requesting

$2.5 million for Program Direction. This funding will provide salaries, benefits, travel and support of 45 FTE's to manage the Buildings and Community Systems program.

MULTI-SECTOR

We are requesting $24.1 million for the Multi-Sector Programs which include the Energy Conversion and Utilization Technologies (ECUT) Program, Conservation Program International Research Monitoring (IRM), Conservation Program Analysis and Planning (CPAP), the Inventions and Innovation Program, and the National Appropriate Technology Assistance Service (NATAS). It includes $17.8 million for ECUT, $0.25 million for IRM, $0.30 million for CPAP, $3.85 million for the Inventions and Innovation Program, and $0.5 million for NATAS. The budget request also includes $0.1 million in capital equipment, $0.544 million in program direction to support FTE's for Multi-Sector programs, and $0.759 million for Technology Assessment and Transfer.

ECUT Program research activities are interdisciplinary in nature. ECUT seeks to capitalize on basic research breakthroughs to address "real world" problems which cut across more than one energy consuming sector. ECUT research results in improved understanding of materials problems and also provides predictive models and design tools useful to the private sector for achieving greater energy productivity. The ECUT interdisciplinary technical areas are: Combustion, Thermal Sciences, Materials, Biocatalysis and Tribology.

In FY 1990, $3.8 million is requested for the ECUT Combustion Program. ECUT Combustion research provides analytical and measurement techniques needed to understand the thermochemical and related processes that take place in the combustion of fuels and in the conversion of the released thermal energy to work. The results of this research are being used by the U.S. auto industry and others in the private sector to develop more efficient, reliable, and clean combustion systems and devices. This activity is especially significant since the reduction in the use of fossil fuels by more efficient combustion systems would lead to reduced emission of carbon dioxide and nitrogen oxides.

The $1.6 million requested for the ECUT Thermal Sciences Program will be used to develop improved thermodynamic and fluid dynamic analytical capabilities and experimentally validated computerized data bases. These are needed to improve the efficiencies of a wide variety of energy conversion processes and provide an improved heat and mass transfer technology that will optimize utilization of the thermal energy released by combustion of fuels. Application of this research to cooling and refrigeration systems will contribute to the U.S. response to the international concern on chlorofluorocarbons (CFCs) which are of concern both as so-called "greenhouse gases" and as a threat to the stratospheric ozone layer. Alternative refrigeration and space conditioning technologies that do not use CFCs will be investigated and property characteristics of alternative working fluids to replace CFCs in conventional technologies will be undertaken.

The $7.0 million requested for the ECUT Materials Program will be used to continue to investigate energy conversion applications of the new high critical-temperature superconducting materials. In addition, research will continue to develop high-temperature structural materials (new and different ordered metallic alloys and ceramics); to pursue research on recycling polymers (lightweight materials); to initiate exploration of high temperature corrosion-resistant materials and to develop computer models which will allow for the design of ductile ordered alloys prior to development in the laboratory. In the last regard, we are encouraged by results which appear to explain why the addition of a small amount of the element boron to the ordered intermetallic alloy nickel aluminide renders ductile this formerly highly brittle material. More importantly, this insight has the potential to permit us to extend this knowledge to design ductility into new ordered alloys prior to their ever being made in the laboratory. This capability to design desired properties into alloys could have major implications for the international competitiveness of an important segment of the U.S. metallurgical industry.

The $2.7 million requested for the ECUT Biocatalysis Program will be used to establish a technological data base for high productivity bioreactors needed by private industry in order to manufacture industrial chemicals using biological systems which are economically and energetically competitive with conventional processes. In addition chemical and biological processes will be investigated to identify those that could be used as possible means of removing carbon dioxide and producing oxygen or oxygenated organic chemicals in the process.

The $2.7 million requested for the ECUT Tribology Program will be used for research on high-temperature lubricants, development of in-situ friction and wear diagnostic instrumentation, and for engineering tribological surfaces. While research activities in tribological design tools will be closed-out in FY 1990, new investigations will begin in tribological systems engineering.

The FY 1990 budget request of $0.25 million for the Conservation Program International Research Monitoring will be used to continue to monitor and evaluate the status of foreign technologies related to energy conservation and to compare it with the status of U.S. technologies.

The $0.3 million request for Conservation Program Analysis and Planning will support the development of the Conservation-wide multi-year program plan, as well as associated analyses and assessments which address appropriate issues for a consistent planning framework. The request of $0.1 million for capital equipment will be used to procure small pieces of instrumentation for the ECUT program.

The FY 1990 budget requests $3.85 million for the inventions and Innovation Programs. The Energy-Related Inventions Program was established by Congress to evaluate the technical merits of energy-related inventions submitted to DOE and to provide technical assistance and grants to further develop promising inventions. The National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards, conducts evaluations through its Office of Energy-Related Inventions. Promising inventions identified by NIST are directed to DOE, which may elect to provide Federal assistance when private sector support is not available. From program inception in 1974 through 1988, approximately 25,000 disclosed inventions have been reviewed and evaluated by NIST. Based on NIST recommendations, 300 inventors have been awarded grants totaling $22 million. Of these, at least 73 inventions have entered the marketplace, generating estimated cumulative sales of $350 million and directly creating more than 1,000 jobs. In FY 1990, the requested funding will support approximately 29 of the most promising inventions. During FY 1990, DOE will continue to work one-on-one with inventors to provide commercialization planning assistance and will conduct 3 workshops for recommended inventors to assist them in dealing with the various aspects of bringing these technologies to the marketplace.

In FY 1990, the Inventions Program will continue to identify and evaluate the activities of existing local, state, and regional programs which are working directly with inventors, and determine the extent and success of efforts being conducted by the private and non-Federal public sector to foster technological innovation. In addition, the effort will establish procedures with states and local areas that have innovation support programs to permit the exchange of information and provide for shared support of selected innovative organizations and programs. This Program also supports the Patent and Trademark Office Project XL with technical assistance and information exchange. The goal of this support is to assist Project XL in identifying how to encourage and motivate school children to be inventive. These activities are funded as part of the Technology Assessment and Transfer budget element.

Over the past 7 years the Innovative Concepts Program has provided seed money to conduct preliminary energy and economic assessments of innovative approaches to saving energy in the areas of building materials, industrial processes, industrial separations, and building retrofit. Awards of approximately $15,000 were made to each of 42 researchers selected from responses to RFP's on these targeted topics. A new cycle on innovative techniques for recycling plastics without harming the environment will commence in FY 1990. The Innovative Concepts Program will continue to conduct limited tracking of these researchers in order to determine how many received follow-on funding, how many new inesses were started, how many patents were issued as a result of funding by this program, and whether the approach that we developed is being used as a model at national laboratories to encourage innovation and creative solutions to energy conservation problems. In 1983, the Congress appropriated funds to establish the National Appropriate Technology Assistance Service, the third Multi-Sector program, to disseminate information on conservation and renewable energy technologies and to give advice and guidance in using them effectively. NATAS was formally established in FY 1984, and to date has received over 36,000 requests for information and assistance. The FY 1990 budget request contains $0.5 million for NATAS for continuation of information and technical assistance to individuals and energy-related businesses. (The current rate of inquiries is about 165 per week and the $0.5 million request will provide for continued responsiveness to public inquiries.)

The FY 1990 budget request for Technology Assessment and Transfer activities of $0.759 million for the ECUT and Inventions programs will be used to provide technical and analytical support for management of the ECUT and Inventions programs, to conduct the monitoring of inventors assisted by the Energy-Related Inventions Program, and also to support the Inventions program activities with inventor organizations earlier described.

We are requesting $0.544 million for Program Direction. This funding will provide salaries, benefits, and travel for a staff of 10 FTEs to manage the Multi-Sector program.

INDUSTRIAL PROGRAMS

The FY 1990 budget request for the Office of Industrial Programs (IP) is $16.13 million. These funds will be used to carry out research and development activities in four subprogram areas: Waste Energy Reduction, Industrial Process Efficiency, Industrial Cogeneration, and Implementation and Deployment. The goal of these activities is to encourage improved energy efficiency in industry, which accounts for approximately 36 percent of total U.S. energy consumption, and to provide technologies which offer industry a choice of fuel options. The Department's activities in the industrial area consist of a comprehensive program of carefully targeted technological research and development, combined with the transfer of technology results to the industrial sector for implementation of the research. The R&D activities focus on selected high risk ventures which are not likely to be pursued by the private sector alone. Most of the R&D is carried out by private companies and institutions operating under cost-shared contracts or cooperative agreements with the Department of Energy.

In FY 1990, $6.4 million is requested for the Waste Energy Reduction subprogram, which supports research and development on improved combustion efficiency for industrial furnaces, boilers and process heaters through oxygen enrichment technologies, improved burner designs, and sophisticated combustion controls. The subprogram also supports R&D on waste heat recovery by development of advanced industrial heat pumps, high temperature recuperators, and new ceramic materials for heat exchangers; as well as research into industrial waste materials recovery and utilization. An example of research in this subprogram is the development of a pure low cost silicon carbide powder for making heat exchanger components to reduce the cost and improve the reliability of high temperature recuperators. An offshoot of this work was the development of non-destructive evaluation techniques to determine the integrity of fabricated ceramic parts for use in high temperature service. A private company which worked with Idaho National Engineering Laboratory under a DOE contract now offers this inspection service to ceramic part fabricators.

In addition to ceramic material development, particularly with reinforced fiber materials, efforts will be continued on advanced concepts for heat exchangers, new types of chemical heat pumps for industrial process applications, and the advancement of technologies to utilize wastes through the use of chemical and biotechnology processes.

In FY 1990, $5.3 million is requested for the Industrial Process Efficiency subprogram which includes R&D for advanced sensors and control systems; advanced separation systems; and development and testing of electrode materials for production of aluminum in electrolytic cells. Significant progress is being made in several of these areas, and continuation is planned for FY 1990. The development of stable anodes and cathodes for aluminum production offers great promise in reducing the electrical power requirements for the process. Laboratory work will be conducted in preparation for scaling up to a 20,000 ampere test cell. If successful, the process will be further scaled up to a full-size aluminum production cell in the future. In FY 1990, R&D will also be continued on advanced, on-line, industrial sensors for improved control of a multitude of industrial processes; advanced low energy separation processes using techniques such as membranes, continuous liquid chromatography, impulse drying of wet web materials such as paper, and freeze concentration. All of these efforts offer excellent opportunities to reduce the energy consumption in basic industrial processes.

A minimum of funds is being requested for the Metals Initiative in the FY 1990 budget request since newly-funded projects are just now getting underway. A project for the development of superplastic steel has been funded with Lawrence Livermore National Laboratory and includes sharing of costs by three industrial companies. This project offers the possibility of producing net-shape components with large monetary savings, since machining, joining, and special heat treating procedures could be eliminated. A second project is being negotiated with the American Iron and Steel Institute which involves direct reduction of iron ore.

In FY 1990 $1.63 million is requested for the Industrial Cogeneration subprogram, which focuses on research for cogeneration technologies, such as topping cycles, and the direct conversion of thermal to electrical energy which can either be part of a topping or a bottoming cycle. This program has been very successful in promoting cogeneration technologies which utilize alternative fuels. For example the development of a coal-water slurry fired slow speed diesel was successfully completed under this program. The program overcame the difficulties of fuel handling and injection and obtained sustained running of the test engine with very low emissions. IP research is continuing on the indirect-fired Brayton system, the high temperature steam turbine system and the alkali (sodium) heat engine, which utilize alternative fuels for cogeneration. In FY 1990, $1.63 million is requested to continue the topping cycle and sodium heat engine research.

In FY 1990, $1.1 million is requested for the Implementation and Deployment subprogram. In addition to its research and development efforts, the transfer of technology to industry remains a principal objective of DOE's industrial conservation program. Examples of recent technology transfer efforts include conferences on membrane technology and industrial waste waters as well as preparation of technology transfer documents on R&D in materials development and waste products utilization technology. Economics provide the most important incentive that industries have for adopting more energy-efficient technologies. Thus, the technology transfer effort is designed to focus attention on the economic benefits associated with specific technologies. Industry participation in the technology development process is critical to successful commercialization, and trade associations are typically involved in the technology transfer effort, helping to multiply the effects of the Department's own activities. In FY 1990 work will focus on workshops, conferences, and technical symposia and the development of written materials focusing on technologies developed with DOE assistance. This budget category now includes funding for technical evaluation, analysis and planning support for the total program. This was formerly included in the Waste Energy Reduction Subprogram.

We are requesting $1.7 million for Program Direction. The funding will provide salaries, benefits and travel for a staff of 26 FTEs to manage the Industrial Programs.

STATE AND LOCAL ASSISTANCE PROGRAMS

Program direction funds of $7.6 million are requested for the Office of State and Local Assistance Programs (OSLAP) to provide for program management of prior year Federal grants and monitoring and oversight of Exxon and Stripper Well overcharge funds distributed to the States. Our request will cover salaries and expenses for 95 FTE's at Department of Energy headquarters and field offices. Program direction funds will be used for contractor support for analysis, evaluation, and technical assistance.

As the result of Court decisions in the Exxon, Stripper Well, and other oil overcharge cases, the States have received $3.6 billion for use mainly in five Federal energy grant programs--the four State and Local Assistance

Programs in the Department of Energy and the Low-Income Home Energy Assistance Program in the Department of Health and Human Services. This large disbursement was a substantial increase over annual appropriated fund levels and as of December 31, 1988, the States have allocated about 84 percent of their total receipts. Future overcharge recoveries to be returned to the States are estimated to be $600-750 million. No DOE grant funds are requested in the FY 1990 budget. These programs are not being terminated; they are being supported by non-appropriated funds.

Our goal has been to enable State and local governments to develop more non-Federal funding for their energy programs. To that end, our efforts have focused increasingly on identifying and establishing private sector sources of funds and on developing mutually beneficial working relationships between States and other groups that will help them continue and expand their most successful and highest priority activities. In recent years, energy partnerships have been developed, and opportunities for shared savings and income-generating projects have been demonstrated and put into practice. There has been a concerted effort to remove institutional barriers to increased energy efficiency and to encourage and facilitate use of advanced conservation technologies.

RENEWABLE ENERGY OVERVIEW

Renewable energy has seen a dramatic increase in its contribution to the nation's energy supply, having grown by almost 30% in the last decade. Today, renewable energy technologies provide over 9% of the nation's total energy supply, the equivalent of one month of U.S. energy consumption each year. Mature renewable technologies like hydroelectric power and direct combustion of wood provide this contribution across the range of end-use sectors, including utilities, industry, and commercial and residential consumers. Emerging technologies such as photovoltaics, geothermal, solar buildings, and wind energy have experienced rapid growth in recent years, and play an increasing role in regional as well as state and local markets. As an illustration, photovoltaics, with favorable economics and reliability as a stand-alone small power source, has emerged as today's technology of choice to meet essential needs in remote areas, for applications such as refrigeration, irrigation, and rural electrification. In addition, nearly 40 utilities across the country have conducted pilot programs in both central station and distributed tests of photovoltaics, to move this technology closer to bulk power applications.

Since the dawn of the industrial age, America's economic competitiveness at home and abroad has been shaped and influenced by energy, which plays a role in the production of goods and services in every economic sector. America's economic competitiveness has also been shaped by technological advances that increase growth and productivity. Coming full circle, these technological advances will enable Renewable Energy technologies to mature and support U.S. industrial development. The vast energy resource that is represented by renewable energy can be increasingly used in the future through developing the sophisticated ability to capture and deliver the resource at a competitive cost. With a continued national investment in improving the technology, renewable energy can provide dividends in supplying energy in all the major forms needed in this country, from electricity to liquid and gaseous fuels, to industrial process heat and the direct space conditioning and lighting of buildings.

The projected growth of these energy needs is substantial. By the turn of the century the U.S. is likely to require 50 to 120 Gigawatts of new electrical generating capacity to meet demand growth. Substantial capacity will be needed to replace existing plants that will have aged past their useful life. With respect to energy use in the transportation sector, the number of passenger vehicles on our roads has increased by over 50 million vehicles since 1973, consistent with an expanding, maturing, more mobile population. Major improvements occurred over the last decade in the efficiency of the average vehicle; continued improvements are projected, but at a more moderate rate. As a result of these factors the transportation sector energy consumption continues to grow.

This energy demand growth, which stems from a competitive and productive national economy, presents an opportunity for renewable energy technologies to provide a growing share of the country's energy supply. In recent years, renewable energy technologies have made significant inroads and are now a vital element of the continued diversification and security of our domestic energy portfolio. Progress through collaborative R&D with private industry and state agencies has established a foundation for an even larger renewable energy contribution in the future. In striving for goals such as reduced system costs, increased performance, and improved reliability, the renewable energy research program has experienced many successes. Some illustrative examples include:

> The Scott Paper Company recently began a program based on the results of DOE biofuels feedstock research to develop short rotation forestry. The company is planting 400 acres of hybrid trees at its own expense for combustion to generate electricity for a pulp and paper process plant. Based on conversion technology research at the Solar Energy Research Institute a biomass gasifier concept is being commercialized by SynGas Inc.

in a wood-to-electricity facility presently under construction on Long Island, New York.

Researchers in the DOE Photovoltaics program continued an exemplary pace of accomplishment, setting four world records for electric conversion efficiency in advanced amorphous silicon and in multijunction photocells in 1988. The U.S. is now considered the world leader in amorphous silicon photocell development; and exploiting DOE-funded research, the Chronar Corporation has increased production capacity to such an extent that it is now the world's leading producer of amorphous silicon photovoltaic modules.

In the area of Solar Thermal technology, Luz Incorporated has capitalized on DOE solar trough research and installed 194 MWe of solar thermal electric generating systems in California, with an additional 380 MWe under construction.

DOE Geopressured Geothermal researchers have captured the attention of the oil and gas industry, particularly at the Hulin Well research reservoir, the deepest and hottest geopressured resource yet tested. Texaco is providing assistance in designing and conducting the Hulin test program and in analyzing the test results. DOE coordinated the formation of the Geothermal Drilling Organization (GDO) and the Geothermal Technology Organization (GTO), to serve as mechanisms for Federal/private sector cost-shared research activities; the GDO and GTO have conducted several successful joint research projects, such as the borehole televiewer, high temperature elastomers, and the pneumatic turbine.

Three Pilot Centers established by DOE to accelerate industrial development of High Temperature Superconductivity enabling technologies, have attracted strong interest from U.S. industry, even though the Centers have been in operation for less than one year.

In its first year of operation after purchase by a utility, the Mod 5B wind turbine operated over 5000 hours and produced 6 million Kilowatt-hours of electricity. This is an exceptional performance record for an experimental prototype machine. DOE-sponsored R&D has also enabled industry participants to fabricate and install thousands of first-generation small and intermediate sized wind turbines in U.S. wind farms that now total over 1500 MW capacity.

Ovonic Inc. has commenced production of nickel-hydride C-cell batteries, a battery system developed by DOE researchers. The new rechargeable batteries provide twice the running time for lap-top computers compared to existing nickel-cadmium technology.

Accomplishments such as these demonstrate the ability of the renewable energy program to successfully collaborate with industry to build a technology base that will enhance both energy security and international competitiveness. It is also important to note that industry has already begun to adapt advances such as these into innovative applications other than energy production. The program relies upon the expertise of industry and university personnel -- working in concert with DOE, the Solar Energy Research Institute, and our National Laboratories -- to provide the theoretical and practical intellectual discipline required for the success of such an undertaking. The extensive participation of industry throughout the program - from planning to execution of priority research - builds a sound foundation for the transfer of promising technologies from the laboratory to the competitive marketplace.

Successful renewable energy research will continue to deliver improvements in the capture and delivery of this strategically important resource and lead to substantial returns to the country in the form of energy and economic security, energy diversification and competitiveness, and environmental quality attributable to energy production. In this latter aspect Renewable Energy technologies are an environmentally attractive domestic energy supply option. Municipal solid waste conversion systems today present the opportunity to meet community energy needs while providing solutions to pressing problems in urban areas by reducing landfill requirements. Over the longer term, integrated biomass-to-energy options represent a unique opportunity to achieve virtually zero net emissions of carbon dioxide due to their ability to fix atmospheric carbon within the feedstock. Other renewable energy supply technologies, including photovoltaics and wind, offer similar environmental attractiveness.

Renewable energy represents a very large domestic energy resource. The types of research proposed by DOE for FY 1990 in each of the technology programs will provide a vital impetus in converting a larger fraction of the available resource to productive energy supply.

SOLAR BUILDINGS

Recent research developments have confirmed that the supply of useful solar energy to buildings can be significantly increased through electrochemistry, holography, optical physics, and advanced materials. Among the latest technological advancements, switchable glazing materials, commonly referred to as "smart windows", and new wallboards for building interiors containing advanced phase change thermal storage features show promise of doubling current solar energy contributions to building energy requirements. The FY 1990 Solar Buildings Program budget request of $4.2 million will continue to expand the essential technology base required for industrial development and use of new materials, systems, and related solar technologies.

The FY 1990 Solar Building Program continues research in innovative optical switching films which control solar gains and thermal losses through building apertures. Significant progress has been made towards development of solid-state multi-layer electrochromic film assemblies with demonstrated ability to switch reversibly more than 100,000 cycles. Performance parameters for such glazing films will be established for various building types and climates. For solar cooling, desiccant materials research will focus on development of new, promising non-cross-linked polymeric materials which would be both cost-effective and would provide structural support capabilities for desiccant wheels.

Solar heating research will respond to the solar industry's urgent needs for technical assistance in the development of preferred system designs, test procedures, and acceptance test methods. These activities will provide industry with the technical information it requires for designing, constructing, and maintaining solar buildings.

PHOTOVOLTAICS

The past year brought a major acceleration of technical progress in virtually every photovoltaic (PV) research area, affecting both near and long-term adoption of PV technology. In FY 1990 the program will build on this progress. With its budget request of $24.65 million in operating expenses and $0.4 million in capital equipment, it will emphasize research in thin films and high efficiency materials as well as maintain strong ongoing work in understanding the fundamentals of photovoltaic devices and exploring and characterizing new materials. The program will also seek, through R&D partnerships and collaborative research, to maintain its record of cost sharing by industry. For example, in FY 1988 government contract funds to industry was matched by cost-sharing at over 40%.

Crystalline silicon is the workhorse material of today's PV technology, and modules produced from this material are routinely produced with 13% conversion efficiencies. In 1988, the first commercial delivery occurred for modules with sunlight-to-electricity conversion efficiencies of 15% and higher--a performance goal that had been targeted for the early 1990's. Culminating several years of collaborative research with industry on crystalline silicon technology, these modules have put PV in a good position to economically meet small-scale power needs today. While this intermediate goal is important in maintaining U.S. competitiveness, the program has for several years emphasized research on thin films and very high efficiency materials. The low material usage of thin film offers the promise of lower costs of production. Similarly, the higher output of high efficiency materials helps offset the somewhat greater cost of these materials.

A series of important research advances characterized the thin film effort in 1988. ARCO Solar in Chatsworth, California, with DOE support, greatly improved the performance of an attractive thin film candidate, copper indium diselenide, raising the efficiency from 6.5% for a one square-foot submodule to over 11%. Researchers at Ametek Inc. in Harleysville, Pennsylvania, improved the cell design for cadmium telluride modules, another promising material, and eliminated a problem with the electrical contacts, opening the way for broader development. Also this year, in polycrystalline thin films made from silicon and deposited on low cost ceramic-on-steel substrates, Astropower, of Newark, Delaware, increased small-cell efficiencies from 8% to over 14%.

The three-year, cost-shared program in amorphous silicon research also continues to show a good return. At Solarex Corporation in Newtown, Pennsylvania, large one-square-foot modules (which have historically reflected major efficiency losses compared to small cells due to manufacturing nonuniformities) are now achieving over 6% efficiency using amorphous silicon alloys with carbon and germanium. And, the largest two-cell modules at the 6%-efficiency level--three square feet -- are being made at Chronar Corporation in Princeton, New Jersey. Researchers at Energy Conversion Devices in Troy, Michigan, have made a smaller laboratory device with an efficiency of over 13%. While future uses may include power modules for utilities, today amorphous silicon cells and modules are the heart of the revolution in solar-powered consumer products. In 1987, the last year for which data is available, amorphous silicon accounted for 37% of photovoltaic energy products sold.

Displaying the highest efficiency of any solar cell material, gallium arsenide solar cells are being developed for use in concentrator modules and other specialized applications. Spire Corporation in Bedford, Massachusetts, achieved a new efficiency record -- over 24%-for a gallium arsenide cell under unconcentrated light. At Kopin Corporation in Taunton, Massachusetts, researchers are making thin-film gallium arsenide cells with 22.4% efficiencies for use in flat-plate modules. And researchers at Varian Associates in Palo Alto, California, designed a cell that has achieved 29% efficiency under concentrated light. Sandia Laboratory researchers used this type of cell in a tandem configuration with a silicon concentrator cell from Stanford University. The combination resulted in a new world record for all solar cells -- 31% efficiency under concentrated light.

While the gains in photovoltaics thus far have provided major advances in performance and cost, much more research and development is ahead. Today electricity produced by photovoltaics costs 25 to 35 cents per kilowatt-hour. Depending on the size of the system, this represents the beginning of the cost competitive range for remote and high-value energy markets. Wider and more cost-effective applications will require a combination of materials and cell design advancements, with more emphasis on fabrication methods and process experimentation. It is not known yet which material or technology will enable photovoltaics to achieve the program goal of 6¢/kWh which would establish PV as a widespread electric power supply option.

For thin films in FY 1990, a collaborative project or polycrystalline materials, following a pattern similar to the successful multi-year cooperative effort on amorphous silicon, will be initiated and will involve up to six industrial teams. Emphasis will be placed on investigating copper indium diselenide, cadmium telluride, and thin-film silicon and on exploring deposition processes of spray pyrolysis, electrodeposition, and evaporation.

In the high efficiency materials research area efforts will focus on flat plate concepts using silicon and on concentrator cell designs using either silicon or so called "three-five" materials such as gallium arsenide and aluminum gallium arsenide. For concentrator designs, achieving cell efficiencies greater than 30% at 500 suns is a critical research objective. Efforts supported by the FY 1990 budget request will be aimed at cascade cell designs, mechanically stacked designs, as well as improved understanding of electrical properties at the material interface relative to surface passivation and internal quantum efficiencies.

In FY 1990 fundamental research will be concerned with several different activities that cut across the more specific and directed collaborative research with industry. Four of these activities are currently performed within the SERI laboratory and are considered world class efforts. SERI has unique and well recognized in-situ and post fabrication electro-optical characterization capabilities and performs advanced surface and interface analysis on a variety of materials; over 3000 material samples are analyzed at SERI's measurement laboratory each year. SERI crystal growth laboratories are directed toward improved understanding of the role played by localized point-like defects in determining PV performance levels in high quality silicon material. SERI's solid state theory research leads the world in investigating innovative concepts and in the selection of novel and new materials for further research and development. Solar radiation research investigates the relationship between the various portions of the sun's natural spectrum and cell design and performance. Funding is requested to continue these activities in FY 1990.

DOE's Collector Research effort currently emphasizes cooperative test programs with manufacturers and application sectors and will continue to do so under the FY 1990 budget request. *In systems research, program focus* will continue on refining the understanding of operating systems. This work is complemented by the Design Assistance Center which interfaces with users, provides up-to-date design practices, assesses the impact of new collector designs on overall system operations, and gathers and reports on long-term performance data for selected PV systems.

SOLAR THERMAL ENERGY

Solar Thermal Energy research focuses on concentrating solar energy to meet U.S. energy applications and needs. Concentrated sunlight is a very versatile and high-quality form of energy and thus, solar thermal technology has a broad range of industrial and commercial applications. Solar thermal energy systems concentrate the sun's radiation for thermal energy applications to generate electricity and process heat. Energy from Solar Thermal systems can also be used for concentrated photon applications, such as enhancing chemical reactions for the detoxification of solid and aquious waste and for the processing of materials.

The DOE Solar Thermal Technology Program is structured both to conduct core R&D and to permit collaboration in industrial applications. The results of past solar thermal R&D have supported industry in bringing to the marketplace systems that utilize centrally located engines and first-generation concentrating collectors. One example of success is the seven LUZ SEGS plants in California which, combined, generate 194MWe. LUZ has 380MWe of additional contracts with Southern California Edison and future opportunities for additional systems throughout the United States and in India, South America, and Africa.

Additional advances in solar thermal technology are required for systems to be competitive beyond these first few niche markets. Thus research is continuing on components that will cost less and have improved performance, reliability, and efficiency.

The Solar Thermal budget request of $13.2 million operating expenses and $0.2 million capital expenses for FY 1990 supports those activities which address the most critical technical uncertainties and performance and cost improvements necessary to achieve energy cost goals. Those activities include: Collection Technology Research, Energy Conversion Technology research, and System and Applications Technology.

The funding requested for Collection Technology activities will support research on silvered polymer optical materials to improve their performance, durability, and soiling resistance. Efforts to develop commercially viable innovative membrane heliostats and dish concentrators that achieve dramatic reductions in weight, material requirements and cost will be continued. Research on an advanced falling salt film direct absorption receiver and a sodium reflux receiver will be conducted. If successful this could result in significantly improving the efficiency and lowering the costs of central receiver and parabolic dish systems.

The funding requested for Energy Conversion Technology activities will continue the development of advanced, long-life, dish-mounted heat engines. This is a heavily cost-shared activity with industry to develop highly reliable, mass-producible, low-cost engines. Basic research on solar direct conversion and materials treatment in the area of concentrated photon applications will be continued.

Under System and Applications Technology, the FY 1990 budget request will continue to support comparative analysis of technical alternatives on advanced concepts and applications. Central receiver and dish Stirling system design and analysis including component and subsystem testing and evaluations will be conducted. The research emphasis is on developing crucial components and systems needed to establish technical readiness of electric power production applications in major domestic markets by the late 1990s. The program is also investigating how to achieve significant reduction in the cost of electricity from currently available solar thermal systems and hopes to pursue collaborative R&D with an industrial partner.

BIOFUELS

The Biofuels and Municipal Waste Technology Program focuses on developing technologies that can produce liquid fuels from renewable resources. These fuels can be produced from most plant material as well as waste products such as municipal wastes via thermochemical and biochemical conversion processes.

Approximately 3 quads of energy, representing 4% of U. S. energy supply, are currently generated from biomass and wastes. While this represents a significant contribution, current applications have yet to exploit the major potential for biofuels: the ability to provide affordable liquid fuels, the energy products the Nation needs most. Estimates of the energy potential of biofuels range as high as 17 quads annually, or 20% of current energy consumption. Developing the capability for achieving this potential is the goal of the Biofuels and Municipal Waste Technology Program.

The Program's research focuses on fuel pathways that combine a biomass feedstock, such as terrestrial energy crops, with a conversion process to produce alternatives to fossil-based liquid fuels. The end products of these pathways will include economic alcohol fuels, gasoline, and diesel fuel. The FY 1990 Budget Request for Biofuels and Municipal Waste Technology is $8.48 million for operating expenses and $0.6 million for capital equipment.

Terrestrial crops research focuses on short rotation woody crops (SRWC) and herbaceous energy crops (HEC) that are 5 to 10 times more productive than standard forestry and agricultural practices. Certain elements of this research, such as increased growth, environmental requirements, and monoculture viability, apply to all fuel pathways, while other research tailors characteristics such as lignin, moisture and ash content to facilitate specific conversion technologies. Techniques for improving terrestrial energy crops under investigation include advanced genetic and biotechnological methods. SRWC research continues to focus on Populus as the leading wood energy species. Industry cost-shared monoculture viability studies will continue. HEC species screening will be completed for the Midwest and Southeast, with carefully selected species targeted for genetic improvement.

Aquatic energy crops research continues to concentrate on increasing the productivity and oil content of microalgae for the production of diesel fuels. Advanced genetic engineering techniques are being applied to candidate microalgae strains to improve oil production and quality.

Performance of selected strains will be evaluated under real world conditions at the outdoor test facility in New Mexico. Engineering design considerations for efficient microalgal production will be evaluated to address hydrodynamics, evaporation and percolation.

Thermochemical conversion research focuses on production of biomass-derived gasoline and methanol. The conversion of biomass to methanol currently requires that biomass first be converted to a medium-BTU gas (syngas). During FY 1990 research will focus on conversion of syngas to methanol by delineation of gas clean up, gas compression, and gas hydrogen-to-carbon monoxide ratio steps. Biomass also can be thermochemically converted to gasoline. Research is currently focused on two competing routes. One produces biocrude oil which must be hydrogenated, and the other produces a vapor product which is then passed over a catalyst. During FY 1990, bench scale research will be completed and the two routes evaluated to select the most promising route for future research.

Biochemical conversion research is aimed at the production of fuel ethanol from non-food biomass feedstocks. Specific research focuses on the conversion of cellulose and hemicellulose, the two principal components of terrestrial energy crops, to sugars that are then fermented to ethanol. During FY 1990, researchers will use biotechnology and genetic engineering to develop improved organisms for better conversion of cellulose and hemicellulose to ethanol. In addition, research will be conducted on improved reactor concepts to reduce the cost of ethanol from biomass.

In FY 1990, capital equipment funds will be used to continue R&D momentum by providing research centers with state-of-the-art equipment capability. Specific equipment requirements include the need to operate the outdoor microalgae test facility and to upgrade and replace obsolete laboratory equipment.

WIND ENERGY

Wind energy research is paying off in continued improvement in wind plant operational performance, energy production, and reliability, but substantial additional advancement is needed to allow wind energy to be a practical power source for U.S. and worldwide markets now believed to exist. Today more than 16,000 wind turbines, totalling over 1,400 MW of electric production capacity are operating in the U.S. During 1988 alone these turbines produced 1.7 billion kilowatt-hours of electricity. The domestic and emerging world interest in wind energy potentially represents a major market for US companies that have kept up with the rapidly advancing wind technology. Recognizing that other countries have major interest in wind energy research, development, and demonstration programs, the DOE wind program emphasizes the research necessary to maintain the competitiveness of the domestic industry.

Several major accomplishments were achieved as a result of the DOE wind program in 1988. In January the 3.2 MW Mod-5B turbine was turned over to the Hawaiian Electric Company for routine utility operational testing. One year later, the machine has completed over 5000 hours of operation producing nearly 6 million kilowatt-hours for Hawaii. This is considered a major accomplishment for an advanced turbine that is the largest in the world. Also, the 34 meter diameter, 500 KW experimental Vertical Axis Wind Turbine (VAWT), built for DOE by Sandia National Laboratories, was dedicated. Initial test operations have proven highly successful and have shown turbine structural vibration frequencies and resonance damping very close to theoretical predictions. These results are being used to validate new scaled-up structural design models and should allow future Darrieus systems to be built by industry with better reliability and lower structural costs.

Wind energy research during FY 1990 will focus on work to improve the basic understanding of the interactions and physics of wind inputs and wind turbine response. New airfoils and other advanced wind turbine concepts will be tested in wind tunnels and in field evaluations. Theoretical models for predicting turbine aerodynamic performance and structural response will be upgraded with the latest field test results. Industry will be invited to propose scoping studies for advanced turbines incorporating the results of the last five years of research and windfarm operating experience. The FY 1990 request for wind energy research is $8.15 million in operating funds and $0.2 million for capital equipment.

In particular, wind turbine dynamic sciences will be emphasized in the FY 1990 program. Recent tests on arrays of wind turbines in windfarms have shown large atmospheric eddies which for the first time may be defined sufficiently to allow the deterministic prediction of turbulence input to the turbine rotor. This will allow more accurate prediction of structural loads and stresses. Additional field tests are planned in different climate and site conditions to verify these new theories. Research on wind turbine rotor aerodynamics will focus on the study of stall and its effects on performance and control. This work will be greatly facilitated by liquid crystal and flow visualization techniques recently adapted for aerodynamics testing by wind energy researchers.

Cooperative cost-shared field testing using commercial turbines in windfarms has proved to be a low cost method for obtaining needed test data and transferring technology to industry. Cooperative field testing will be continued and expanded in FY 1990 to collect turbine structural and airfoil performance data on new high performance airfoils which have been designed. This approach to testing has the added benefit of facilitating transfer of research results to industry. Studies will also be initiated with turbine manufacturers to examine economics and benefits of new concepts such as variable rotor speed and hinged rotors which have been under consideration for several years. Utility company involvement will also be encouraged in planned studies of electrical system interactions with wind turbines and arrays.

OCEAN ENERGY

The primary objective of the Ocean Energy Technology Program is to advance the knowledge of ocean energy technology to a state sufficient to allow the commercial sector to assess whether applications of the technology are viable as energy conversion alternatives and supplements to current conventional systems. The Federal research program is focused on developing an ocean thermal energy conversion (OTEC) technology base from which industry could develop a 5-15 MWe size system. A key element in this effort is a planned future 165 kW experiment toward which much of the FY 1988 through FY 1990 research is directed. The goal of the program is to achieve long-term technology advancements that could result in a projected total system capital cost of $3200/kWe. The FY 1990 budget request is $2.078 million for operating expenses, with an additional $0.1 million for capital equipment.

The past year was the most successful year to date in the Ocean Energy Technology Program. With the operational success of an expanded seawater supply system at the Natural Energy Laboratory of Hawaii, testing of an evaporator-condenser subsystem using actual seawater was begun. These tests resulted in the first desalinated water ever produced from a prototypical open-cycle OTEC subsystem. In addition, seawater testing of various OTEC components such as mist eliminators and single element flash evaporators verified their analytical model prediction for seawater performance. Initial test data now being generated is the most comprehensive experimental data ever obtained in the OTEC program and shows great promise for the advancement of open-cycle OTEC technology.

Building on this base of technical data, the FY 1990 program will emphasize research necessary to prepare for field experimentation in the Experimental Verification and Testing element of the program. This effort will include the fabrication and operational testing of the Heat and Mass Transfer Experimental Apparatus (HMTEA) at the Seacoast Test Facility of the Natural Energy Laboratory of Hawaii. Through a multi-year component experimentation period, the operation of the HMTEA will focus on obtaining experimental data in seawater to determine the performance of flash evaporators and both surface and direct-contact condensers at a scale approaching the planned 165 kWe open-cycle OTEC experiment.

In the Thermodynamic Research and Analysis element of the program, studies will be undertaken to provide analytical support for the design, performance prediction, and system integration activities in preparation for the 165 kWe experiment. Heat and mass transfer tests will also be continued on multi-element spout evaporators, condensers, components redesigned as a result of previous tests, and other system elements to assess their performance and determine validity of analytical models. At this stage in open-cycle OTEC research, seawater rather than freshwater testing is essential for accurate determination of components and system performance. The availability of the expanded seawater supply and the evaporator-condenser test apparatus provide the program with an opportunity for significant technical advances in the near term.

OTHER SOLAR ACTIVITIES

The Department conducts a number of solar research support activities in addition to the technology development programs. Generic activities including resource assessment, the maintenance of facilities and equipment at the Solar Energy Research Institute, technology information, international, program support, and program direction provide for appropriate planning and direction of the research program and measurement of the complex solar research. Also these support activities provide for effective communication of research results to researchers and the public and provide institutional and technical support to industry in exploiting market opportunities. The FY 1990 budget request for these activities totals $8.911 million.

A reliable solar radiation resource data base is essential to electric supply planners and industrial engineers for designing, siting, and managing efficient, reliable solar power systems. It is equally vital to researchers who require increasingly specific resource data to pursue resolution of the complex scientific issues associated with the solar processes being addressed within the technology research and development programs. The FY 1990 budget request includes $.772 million to continue resource assessment activities that will improve the accuracy of required data from past years; develop a computer-based 30-year solar resource data base; obtain and archive reliable current resource measurements to be added to the data base of selected U.S. locations, and to improve the computer-based models for understanding the temporal variability of the solar resource and its spectral characteristics.

The Solar Energy Research Institute (SERI) is the primary Federal laboratory conducting solar research and development. The $.657 million request for FY 1990 includes items to meet priority needs in both General Purpose Equipment (GPE) and General Plant Projects (GPP). The GPE request of $.482 million incorporates funds to acquired multiprogram use laboratory apparatus including a Fourier Transform Infrared Spectrophotometer for advanced materials analysis and a microbalance system for weighing extremely small material samples, as well as equipment to upgrade and improve the Institute's computer systems. The GPP request of $.175 million includes funds for repair of toxic gas fume hood ventilation systems in older SERI labs and general repair of Institute buildings, roads, sidewalks, and drains.

An integral part of the renewable energy programs is technology information activities, for which we are requesting $1.823 million in FY 1990. Through a variety of activities, such as publications, professional seminars, industry workshops, the SERI Inquiry Service and the Conservation and Renewable Energy Information and Referral Service, the program disseminates technical information about renewable energy to researchers, industry, and the general public.

The Department and the domestic renewable energy industry are collaborating through the interagency Committee on Renewable Energy Commerce and Trade (CORECT), administered by DOE, to coordinate government action to exploit international trade opportunities for renewable energy. For example, activities by CORECT have established a basis for a pretargeted exposure of renewable energy to Caribbean Basin-country markets with full cooperation between the domestic industry, domestic and international lending agencies, the Departments of Commerce and State, and energy officials of the Caribbean nations. The FY 1990 request for international activities of $.554 million will be used to continue the technical assessment, educational, and industry assistance services of CORECT, building towards similar coordinated efforts to facilitate trade opportunities which most effectively match U.S. industry capabilities with significant market opportunities in other areas of the world.

We are requesting $.900 million in FY 1990 for program support activities which provide cross-technology analytical and administrative support to the overall renewable energy research effort. Continuing insight into competing energy markets, the technical issues associated with those markets, and consistent evaluation of technology opportunities is vital to industry and DOE success in targeting and directing technology research efforts.

The FY 1990 request of $4.205 million for Program Direction will support staff activities in project management, R&D coordination, technology information and program and general administrative duties.

GEOTHERMAL ENERGY

The Geothermal Energy Research and Development Program, conducted in cooperation with industry, focuses on the principal geothermal resource types (hydrothermal, geopressured, hot dry rock, and magma) and on energy conversion technologies designed to expand the technical and economic boundaries of this large domestic energy resource. The applied research, technology development, and technology transfer activities that characterize this program will provide a basis for the timely introduction, by the private sector, of new concepts and products into the marketplace. The funding request for FY 1990 for the Geothermal Program is $15.0 million for operating expenses and $0.4 million for capital equipment.

Hydrothermal Research, much of it conducted with industry participation, will expand the accessible resource base by (1) improving techniques for predicting and managing the production of brine from geothermal reservoirs; (2) developing new equipment and materials for service in hot, corrosive geothermal environments; (3) exploring advanced power cycle technologies to increase power generation efficiencies; and (4) developing innovative biotechnologies for geothermal waste handling.

In a cooperative effort with industry, a field case study will test advanced geophysical techniques for finding and evaluating hydrothermal reservoirs. In addition, newly developed tracers and interpretation methods will receive further testing at selected reservoir sites. Research also will be carried out on a cost-shared basis with industrial partners through the Geothermal Technology Organization (GTO); emphasis will be placed on meeting industry's priority research needs, such as advanced vertical seismic profiling methods and field testing of unique chemical tracers to determine flow paths in fractured reservoirs.

Hard rock penetration research will improve the technology and reduce the uncertainty of geothermal well drilling, which currently represents about half of the cost of geothermal power. Geothermal wells exceed the cost of typical petroleum wells by factors of two to four due to generally deeper wells, harder rock, higher temperatures, and more corrosive fluids involved in geothermal reservoirs. FY 1990 efforts include research on wellbore data transmission, temperature-resistant components for drilling, instruments for detecting fractures in rock formations, and drilling fluid loss control. Industry will share the costs of development and testing of advanced instrumentation and drilling technology under the Geothermal Drilling Organization (GDO).

The geopressured research program has succeeded in defining the technical characteristics and recoverability of the large reservoirs of hot brine and dissolved methane that lie beneath the U.S. Gulf Coast. However, the size and reliability of these reservoirs must be verified through long-term research testing. The FY 1990 program includes experimental well flow testing, tests of the conversion of the brine energy content (thermal and chemical) to electricity in cooperation with industry, and supporting research on the dynamic response of geopressured reservoirs to production conditions. During FY 1990, the geopressured research program will continue to collect data on both the long-term performance of geopressured reservoirs at high production rates and the long-term effectiveness of downhole scale inhibitors.

Hot dry rock research involves the technology of heat extraction from man-made reservoirs in crystalline rock. In FY 1990, after final preparations have been concluded, the long-term flow test of the large fractured reservoir at Fenton Hill, New Mexico, will begin. This test will mark the last major milestone in determining the feasibility of current heat extraction methods.

The purpose of the magma energy research program is to develop the technology to locate magma chambers and to extract energy from them.

Substantial progress has been made to date in confirming the location and size of a large continental magma chamber, evaluating methods of energy conversion, and developing alloys, well cements, and instrumentation capable of performing in the 800 to 1200 degree Celsius magma environment. In FY 1990, the exploratory well at the Long Valley caldera in California will be deepened, and scientific experiments will be conducted in cooperation with other Federal agencies, using the magma well as a major contribution and a unique "Hole of Opportunity" under the Continental Scientific Drilling Program.

ENERGY STORAGE AND DISTRIBUTION

The use of electricity in the United States continues to expand due to its convenience, dependability, versatility, safety, historical efficiency, and cost to the consumer. But the traditional roles of utilities, industry, and regulators are rapidly changing - in ways that present new challenges for maintaining a secure and reliable electricity supply. The task of operating electric power systems is becoming more complex due in large part to the changing infrastructure of electric utilities since the 1970s. The trend by electric utilities toward purchasing power from independent producers instead of installing additional generating capacity requires that advances in grid management be made to ensure future adequacy and reliability of supply and distribution. Significant penetration of renewable energy technologies or demand-side technology into the nation's power system will further increase the complexity of operations. Planning and operating tomorrow's power system with many small generating units is more difficult than a typical system of today with a few large units - especially when a substantial fraction of the supply may be intermittent.

The Office of Energy Storage and Distribution (OESD) is planning for a secure energy future, both to ensure that emergency needs can be met and to meet the requirements of an expanding economy. The Office is developing technology options which can reduce the nation's vulnerability to major changes in energy availability and in demand profiles. The need for these new technologies will be especially critical in times of national emergencies. Technologies being developed as a part of OESD's projects should find important applications in the nation's transmission and distribution systems.

ELECTRIC ENERGY SYSTEMS

Research in the Electric Energy Systems (EES) Program is designed to provide a technology base to enable the future electric energy network to operate more reliably and more economically while protecting public health and safety and providing electric energy system options by which the nation's security may be maintained. The FY 1990 budget request for the Electric Energy Systems research is $17.3 million.

The FY 1990 EES request includes some $12.1 million for translating recent scientific breakthroughs in high temperature superconductivity (HTS) into technology applicable to the future electric energy network. This HTS technology has great potential for electric power systems when applied to, for example, cables, generators, motors, transformers, storage, and control and protective devices. Greater system efficiencies, improved system stability, and reduced costs are all possible if the technology can be applied to these devices. Presently HTS conductors have poor current density, are too brittle, and degrade too rapidly. Designers are not able to create practical HTS devices at this time. Progress over the past year is laying the technical and institutional foundation for solving these very difficult problems. The HTS program has two important thrusts: to foster collaborative research between industry and federal laboratories (the Pilot Centers) and to develop HTS technology needed by industry (the STEPS research program).

The first thrust involves the new superconductivity Pilot Centers. Locations are Argonne National Laboratory (IL), Oak Ridge National Laboratory (TN), and Los Alamos National Laboratory (NM). Each Pilot Center will develop its own programs and also provide innovative channels through which private industry can tap the resources and expertise of one or more of the national laboratories. The channels can include collaborative projects pairing researchers from the laboratories with those of private firms; work contracted by industry to be done at the laboratories; staff exchange; and licensing of superconductivity patents for commercial application. The Pilot Centers use simplified and expedited contracting procedures and can make flexible arrangements for the disposition of patents and other intellectual property rights. They also have outreach programs designed to seek corporate partners and to acquaint industry with national laboratory capabilities and resources which include: "user-oriented" facilities and current activities that might form the basis for collaborative projects. Private sector interest in collaborative agreements with DOE has increased enormously since Pilot Center formation.

The second is the applied research thrust. This activity, Superconductivity Technology for Electric Power Systems (STEPS), began in April 1988. This applied research program targets large-scale applications requiring high current in magnetic fields. The wide range of potential commercial products to which this technology may be applicable includes cables, motors, generators, and energy storage magnets. The immediate STEPS focus is development of practical HTS conductors from either bulk materials or thin films. This multi-year program will conclude with industry development of prototype HTS devices. Participation by national laboratory, university, and corporate research partners is a key part of nine STEPS projects. Fundamental materials work at each of the laboratories provides a base for the applied STEPS research. Industry and university partners bring additional capabilities necessary to form strong teams for these research efforts.

The FY 1990 EES program will also continue to support research activities in Electric Field Effects and Reliability Research. Electric Field Effects research activities will focus on investigating the impact of combined electric and magnetic fields on living tissue, whole bodies, and abnormal cell growth. Examples include research to evaluate the effects of mixed fields on the behavior and endocrinology of baboons and to investigate the possible relationship of mixed-fields exposure to abnormal cell growth in small animals. Research results in this area continue to be transferred through public fora and technical papers and are the basis of important international research.

The Reliability activities in FY 1990 will continue research on assessing the impacts of a high energy Electromagnetic Pulse (EMP) on the nation's electric power systems operations and developing control and operating strategies to mitigate the effects of an EMP. Assessment and modeling of real power systems are virtually complete; experimental verification of these models will begin in FY 1990. Methods and strategies to operate complex, very large integrated electric power systems through improved system stability, operational, and restoration techniques (on-line detection and recognition research) will be completed. Research into the integration of renewable energy and storage devices into power systems will be initiated.

ENERGY STORAGE

The Energy Storage program conducts research to provide the technology base needed for the development of advanced storage technologies. The FY 1990 request for Energy Storage research is $8.562 million in operating expenses with $.027 million in capital equipment. This request includes $0.35 million for superconducting magnetic energy storage (SMES).

The program focuses on fundamental and applied research for advanced energy storage systems that will improve the efficiency of energy use and enhance the use of the nation's renewable energy resources. This program encourages international cooperation and information exchange on the latest technology developments of advanced energy storage systems worldwide. The energy storage program ranges from fundamental research to exploratory development of technical concepts, and includes research on new concepts, materials, and components. The energy storage technologies which result from areas being pursued within the DOE programs include batteries, fuel cells, thermal storage and superconducting magnetic energy storage. The energy storage technologies provide an alternative for supplying future energy needs, extend the useful life of existing utility central generating equipment, increase the economic attractiveness of renewable energy generating sources, and address the needs for alternate transportation options. As renewable energy sources become even more competitive and the penetration into the energy networks increases, the need for energy storage for intermittent energy sources will become more important in various applications.

In FY 1990 the Electrochemical Storage research activities will continue toward determining the structure, composition, and mode of formation of surface layers on solid and porous electrodes; understanding electrolyte transport; developing new electrochemical couples; and design and fabrication of battery and fuel cell components. New instrumentation will permit the study of the relationships between the kinetics of electrode processes and the atomic structure of the electrode surfaces. Other electrochemical research priorities for FY 1990 include improving the reliability of the electrolytes for fuel cells and batteries; continuing evaluation of sodium/sulfur cells designed for electric vehicle applications; and developing new sodium/sulfur and zinc/bromine cells having the improved durability and reliability necessary for electric vehicle and load leveling applications. Electrochemical progress in the past year has included greatly improved solid electrolyte materials, new membranes for fuel cells, and advanced air electrodes, all of which will contribute to higher levels of reliability and reduced costs.

In FY 1990, research will continue to determine feasibility of smaller capacity, lower cost, and environmentally safe superconducting magnetic energy storage (SMES) devices for utility load leveling and other applications. Past experience with low temperature SMES points to the opportunity for very high energy efficiencies with round trip efficiency of about 90% being typical compared to some 10% less for advanced battery storage systems. The SMES system responds to load change more rapidly (<1sec) than other storage systems.

Thermal and Chemical Storage research in FY 1990 will focus on improving the technical and economic viability of seasonal thermal energy storage for commercial and industrial application. Chemical-Hydrogen Systems will continue research on hydrogen including materials for advanced electrolysis.

GEOTHERMAL RESOURCES DEVELOPMENT FUND

The Geothermal Resources Development Fund was established to guaranty private lenders against losses on loans made for the development and use of geothermal energy. The FY 1990 request is $0.75 million in operating expenses which allows for monitoring outstanding loans.

CONCLUSIONS

The programs presented for your review today show enormous potential for the future. Collectively, their potential applications are expected to ultimately make them highly attractive candidates for private sector development and deployment. These technologies promise increasing competition within the energy marketplace.

The programs represent a solid commitment to the continuing development of these technologies. We are confident that our proposals will increase understanding of the potential for virtually all of the most promising renewable energy options and conservation technologies and will substantially contribute to the base of technical information required for informed decision making by industry and consumers. This is a budget which I believe seriously recognizes today's fiscal responsibilities, as well as tomorrow's anticipated needs.

Thank you for the opportunity to present our budget request.

ATTACHMENT

CONSERVATION SUCCESSES

I would like to mention some of the major accomplishments achieved during Fiscal 1988 in the Conservation program. We are pleased to be able to identify certain accomplishments that can contribute both to energy efficiency and to manufacturing productivity and thus enhance the international competitiveness of our domestic industries.

In the Multi-Sector program, in cooperation with the private sector, a number of organisms have been isolated which extract phosphate from the insoluble phosphate ore. The result is a more efficient process. FMC, Inc. the largest phosphate producer and user of electricity in Idaho, is now co-funding further research with DOE.

In the area of combustion research, the capability for non-obtrusive in-cylinder measurements of fluid motion and flame kernel development in production engines has been developed. The measurements are necessary in understanding the actual conditions that cause idle roughness and lead to inefficient combustion. To make these measurements, an innovative fiber-optic instrumented "spark plug" was fabricated to "see" into a running reproduction engine cylinder without interfering with its operation. The testing of this product in a Chrysler 2.2 liter engine was cost-shared with the Gas Research Institute. The "Big Three" U.S. Automakers have expressed interest in this device. This new device has been trademarked the "Barrack-Witze" Sparkplug and will be marketed by Barrack Technology Corp. of Massachusetts.

The Energy-Related Inventions Program provided assistance to an inventor to develop a new design for precision bearings. The potential breakthrough could have wide-ranging applications from submersible pumps to computer printers. The bearing could be produced domestically at a fraction of the cost of imports and would enhance the design of more efficient machinery.

Support was also provided for the development of electronic octane. This automotive engine ignition control system saves fuel by using knock sensors in individual cylinders to control spark timing. The technology is being used in Jeeps, Ford products, all Chrysler turbos, and has also been licensed to a European ignition system manufacturer, Robert Bosch.

The Industrial Program, in a joint project with the Solar Energy Research Institute, has successfully run a continuous extraction system to obtain a phenolic-rich fraction bark and sawdust wood waste pyrolysis oils. The phenolics fraction from wood is an ingredient identical to one in adhesives used in making plywood, chipboard, and moldings. Wood wastes can thus displace present adhesives derived from petroleum. These resins are being tested by Weyerhaeuser, Boise-Cascade, Georgia-Pacific, and other interested end-users and producers of resins.

The Industrial Programs is working with Allied/Signal Engineered Materials Research Laboratory on a cost-shared basis who has developed a membrane system that provides alternatives to existing energy-intensive distillation and other processes for the separation of petrochemical streams. A cost-shared field test at an Exxon facility in Artmore, Alabama has continuously and successfully separated hydrogen sulfide and carbon dioxide from natural gas. The field test data are being evaluated by Exxon to determine the system's economic and technical viability.

In the area of high temperature burner duct recuperator systems, two prototype ceramic high temperature heat exchangers that operate in environments up to 2,300^{0}F exhaust streams have completed field testing. The first unit, which recovers 5.6 million Btu/hour, was tested successfully at the Cameron Iron Works plant in Houston Texas. The second unit, developed jointly with Babcock & Wilcox, provides burner duct heat recovery from fouling exhausts of 2,000oF at a steel soaking pit in Koppel, Pennsylvania, saving 1.3 million Btu/hour, representing 40 percent of the soaking pit's fuel consumption. These first-of-a-kind recuperator systems, used for preheating combustion air, are providing the basis for the design of second- and third-generation commercial units.

Support was also provided on a cost-shared basis with Union Carbide for the use of oxygen-enriched combustion air to decrease the nitrogen pass-through in boilers and furnaces and improve their overall operational efficiency. A one ton/day scale model Pressure Swing Absorption oxygen supply unit for use in oxygen-enriched combustion systems passed its reliability and performance test very well. This unit, when it completes its associated combustion system testing, will provide design information for a 15-20 ton/day production unit to be used in a glass production factory where it is expected to decrease fuel consumption by 25 to 30 percent.

In the Buildings and Community Systems program, DOE granted a patent waiver to Martin Marietta Energy Systems on a dual-loop triple-effect absorption chiller cycle conceived at the Oak Ridge National Laboratory. This next generation cycle represents a 50% improvement in cooling performance over state-of-the-art absorption chiller technology. Trane Co. has been awarded a license and the Gas Research Institute has agreed to cosponsor further development with Trane Co.

To contribute to energy efficient building designs, the Oak Ridge National Laboratory has recently published a comprehensive Building Foundations Design Handbook which integrates both energy and non-energy elements of foundation designs. It has been enthusiastically received by the industry, is referenced in the 1989 ASHRAE Handbook of Fundamentals, 1989 Model Energy Code, and the proposed revision of the HUD minimum property standards.

Because of suspected adverse environmental effects of conventional CFC materials used in cooling and insulation applications, the Department is investigating possible substitutes. A systematic analytical investigation conducted by Oak Ridge National Laboratory has identified several promising refrigerant mixtures that have not been identified by other researchers. The results are guiding the selection of test refrigerant mixtures on the laboratory breadboard test rigs at the national laboratories. In a related effort, ORNL and a chemical company entered into a proprietary research effort which identified a substitute refrigerant mixture which has the potential to be as efficient as CFCs today.

In the Transportation program, the first phase of design and procurement of improved ceramic components for an automotive gas turbine has been completed. These components, when developed, will enable operation of small gas turbine engines at temperatures in excess of 2500^{0}F, thereby providing potential efficiency improvements of more than 30% over today's technology.

Caterpillar, Inc., in cooperation with our Transportation program, has introduced a method of applying a plasma sprayed zirconia ceramic coating on valves in their 18.5 Litre, 3600 series engine which operates on residual fuels to protect against corrosion and extend valve life. These engines are used to power ships and large stationary equipment. The coating is being applied using the processes and equipment developed for the Transportation program's low-heat-rejection heavy-duty truck engine project.

In Federal buildings, progress in Federal energy conservation shared savings contracts presents an opportunity to expedite energy efficiency in Federal facilities. Private sector installation of needed energy efficiency retrofits at no cost to the government in return for a share of the saved energy costs is now beginning to be successfully implemented by the U.S. Postal Service and the Department of the Army.

DISCUSSION

Mrs. **Lloyd**. Thank you very much, Dr. Berg, for your excellent testimony. And we will be reviewing it not only today, but later on as we progress through the year's activities.

I think you know that one of the major thrusts of this Subcommittee this year will be technology transfer. I notice in the building of community systems that you have $1 million for technology assessment and transfer.

Do you really think this is accurate when you look at the need to get our technology to the marketplace as rapidly as possible? That this could possibly do justice to what we know is before us with our energy needs?

Dr. **Berg**. That is an interesting question, Madam Chairman, because in every one of our programs, we try to get cost-shared research going. And that is really where the tech transfer begins.

So, although you see a line item budget there for tech transfer, there is far much more tech transfer that occurs in our programs than what is actually listed there.

And, in fact, I think that the subsequent witnesses will be showing you some of the devices that they are now manufacturing as the basis of some of the cost-shared work that has been going on as a result of your and our work.

Mrs. **Lloyd**. Do you really feel that there are times that we really take technology right to the cutting edge where we could commercialize it? And at that point, we are not continuing the funding on many of the programs?

I hear this from many of our people, that we aren't watching the technology go to the last final phase where we need a lot of help.

Can you make special consideration in such cases?

Dr. **Berg**. We would like to hear more about that type of complaints. But, I think, at least in the short period of time that I have been with the Department of Energy, I have seen a vast amount of material being turned over to the private industry, where we have gotten tech transfer both in terms of licensing of the research that is going on and actual commercialization by industry of the research that we are working on.

I would be happy to follow up on any further——

Mrs. **Lloyd**. I would like to reemphasize to you and your people that this Committee is very concerned about technology transfer and I hope that you will keep that in mind throughout the year.

Recent discussions of global warming, CO_2 emissions and the burning of fossil fuels has received a great deal of publicity across the country.

And it seems to me, by using more energy-efficient technologies and renewable energy sources, that we can look toward our needs in this area.

Have you really addressed the CO_2 mitigation issue? The CO_2 issue?

Dr. **Berg**. Yes, ma'am. The Department indeed feels that everything that should be done that is cost-effective ought to be done in the area of energy utilization and energy efficiency.

Mrs. **Lloyd**. What mitigation strategies are likely to be endorsed this year? What are your plans to work in this area?

Dr. BERG. First, obviously, everything that we are doing in the area of energy conservation and renewable energies bears on this particular thing that you're talking about.

As far as mitigation, we have specific programs involved in the study of the CFC replacements for refrigeration.

And we are working at Oak Ridge, among other places, with industry in testing new materials and mixtures of non-azeotropic mixtures as replacements.

Mrs. LLOYD. It seems at this time that energy conservation renewable technologies deserve a second look because of their mostly benign emissions.

The budget submission has reduced the activity of the Roof Research Center by 50 percent. I would like you to discuss the Department's long-term plans for the Center, after 1990 specifically.

Dr. BERG. The Roof Research Center is completed and it is on stream. Part of the reduction you see reflects the fact that the construction period is over. I'm happy to say that they have, in 1988, already one co-shared industrial experiment going on. They're about to sign several others.

They are working with both the Navy and the foam installation roofing people in testing membrane material and are about ready to sign a contract to further that.

The Roof Research Center is available. We have got a group of industrial people from the roofing area that are putting together plans in using that facility.

Mrs. LLOYD. For this type of cutback, it must have a major impact on the Center though.

Dr. BERG. The cutback reflects the reduction in funding needed to finish the completion of the Roof Research Center, which was completed last year. It was dedicated in September.

Mrs. LLOYD. But, the funding in this year's budget is what I'm talking about, Dr. Berg.

Dr. BERG. The '90 budget versus '89, were finishing replacing the rest of the equipment in there and it reflects, strictly now, the fact that it is open and ready to go.

Mrs. LLOYD. Because the construction phase is over.

Dr. BERG. Yes.

Mrs. LLOYD. Last year, you know, the Congress passed PL 100-680, the Steel and Aluminum Energy Conservation and Technological Competitive Act of 1988.

Our Subcommittee, as well as the Science Research and Technology Subcommittee, chaired by Mr. Walgren, were instrumental in getting this bill through the House; even though the legislation authorizes $20 million to implement the act in fiscal 1990, the Department has only requested one million dollars.

So we would like you to give us a status report on the implementation of this Act, including the projects that are underway, those that are about to begin and the amount of money that is already appropriated for the Act and whether sufficient funding will be available through 1990.

Dr. BERG. Yes, ma'am. First of all, we wish to thank the Committee for addressing that bill and putting in the wording that they did. As a result, getting the 30 percent cost-sharing by industry has resulted in excellent projects coming forth by the industry.

And I think, again, if I might just say, cost-sharing really brings about technology transfer. If somebody is willing to put up their own money, they are going to make sure that what is done is useful work, that they'll watch what we are doing and direct it the right way. And then, when it is ready to be handed off, they take it and run with it.

Regarding the budget and the $1 million that you talked about, at the time that we were putting together our budget, we had two items on our plate, so to speak—the super-plastic and the spray casting initiatives.

Subsequently, we got an excellent proposal from the American Steel Institute which we are in the process of negotiation; the final negotiation should be done about April, which will require additional funding.

As a consequence, we are proposing to start funding that as well. The one million dollars is not sufficient to do the job in 1990.

Mrs. **Lloyd**. Are you going to have to come back for more money?

Dr. **Berg**. In order to do the job right, to fund the three projects right, we would need an additional $11.9 million.

Mrs. **Lloyd**. Your request is one and you really need——

Dr. **Berg**. If there were more monies to be added, we would recommend adding monies to this project.

Mrs. **Lloyd**. Thank you very much.

Mr. Morrison.

Mr. **Morrison**. I sort of sympathize with you, Dr. Berg. I'm convinced that you folks at the table would love to do more in these areas where you are making progress. And, yet, as I look at your overall budget, in the conservation area, you are cut in half. In the renewables area, you are cut by 25 percent. And I suppose this is another time, Madam Chairman, when the Committee has to step in and make some replacements, do some prioritizing that I guess the folks at OMB refuse to do.

Mrs. **Lloyd**. We will have to make the tough decisions that have to be made this year.

Mr. **Morrison**. I guess that's the job we have.

I want to ask a specific question that is important in my area. I can tell you of the importance of the aluminum anode program to the Northwest and the savings of electricity out there, and making more efficient the aluminum reduction process.

Can you tell me about that program and what plans you have?

Dr. **Berg**. Yes, sir. The aluminum anode research, I'm very pleased to report, is very well. For a while, we had some very grave concerns. Industry did not seem to have a great deal of interest in it. However, after testing a prototype anode, industry now has become most interested in it. There is a test anode being built which will go into a cell, unfortunately in Alabama, for testing to actually run in a production prototype cell.

This cell will be at least 6,000—20,000 versus a normal production cell of 100,000 capacity. But, this is planned to go in this summer, as soon as this electrode is built. The sooner it is built, the sooner they will do it. We are looking at sometime in the June/July time frame in which to insert that electrode into the actual production unit down there.

It will take, roughly, we think, about a year's testing on it to get the full implications of it. If it is successful, it will still be running well beyond that period of time.

Mr. MORRISON. I'm very, very interested in that and would love to come out and look at that as you put that into operation. In fact, this is one area where I hope we can give you a little additional boost as far as financing is concerned.

My other question is much more generic and perhaps reflects what I see happening here in Congress, which is reflective of concerns out across the country. I am looking at the chart that shows free world energy consumption, and it really shows the year 2010 as being sort of a reflection of where we are today.

Renewables, slightly increased chart; nuclear, slightly expanded; coal, rather significantly expanded; gas, about the same; petroleum, about the same.

I'm not so sure that is how people sense that's where we're going to be. And I'm just wondering, within your areas of responsibility, Dr. Berg, are we making the investments we need to? Are we aimed in the directions we need to so that in case we don't have the petroleum to make this chart work and if we can't burn the coal because of the Greenhouse Effect, that we have the answers on a timely basis for this country?

I know it is philosophical, but it certainly relates back to your budget.

Dr. BERG. There is no question that we are under very tight budgetary constraints. At the same time, we accept priority goals to reach certain goals by the year 2010. At this point, we see we would be able to make those goals; it would be stretching, but we can do it.

I think that research we are doing—and I would like to stress that—which has been really set and prioritized by review groups is based on those priorities.

And I don't think industry would argue with the priorities. They may argue about the amount of funding for these things, but they would not argue about the priorities to get us there.

Mr. MORRISON. I think that is an important answer when you're saying that you're headed in the right direction, you're just not going perhaps fast enough as driven by dollars in order to get to where we need to be, or at least so that we have the answers in case that petroleum supply isn't there at a price we cannot afford to pay. And if we cannot utilize the fossil fuels, that you will have the answers for us.

Dr. BERG. We think we will.

As a matter of fact, the fact that we have the two answers to that question I mentioned in my summary statement, the 10-megawatt wood-burning plant on Long Island and the Scott Paper Company work done in Mobile, Alabama, we're seeing more and more people looking at the utilization of wood and forestry products.

We're seeing more and more people finally utilizing what we would call waste as a means of providing energy in our local community.

And if I might just put a little plug in for that:

If any of you Committee Members ever want a look-see at a use of your trash in the right proper way, we would be happy to take you to the two near-by facilities, one in Baltimore where they are cogenerating from municipal waste, electricity and hot water heat, and down in the Arlington County border with Alexandria, where it is strictly an electrical generator, where the trash is being burned to produce electricity.

Mr. **Morrison**. Thank you.

Thank you, Madam Chairman.

Mrs. **Lloyd**. Thank you very much, Mr. Morrison.

Mr. Fawell.

Mr. **Fawell**. Thank you, Madam Chairman.

Dr. Berg, what is the relative importance of advanced battery research for solving some of these environmental problems we hear so much about, like the Greenhouse Effect?

Dr. **Berg**. The advanced battery program, of course, and I assume you are talking about it in terms of electric vehicles, primarily, but we also have the project for electrical storage, it is important.

And, in fact, the electrical vehicle program is moving very well. We see, recently, a very great advance in the flow-through of lead acid battery that was about a 25 percent increase over—is it not? About 25 percent increase over the previous one.

We are concentrating primarily in the area of the sodium sulfur, the lithium metal sulfide batteries.

Mr. **Fawell**. We always hear the cost-efficiency concept and I guess as it relates to burning fossil fuels. Are we getting close in regard to advanced battery technologies?

Dr. **Berg**. Yes, we are. It is my understanding we will shortly see some electric vehicles actually offered for sale, in about a year's time.

I would say this, of course. You still use electricity whether it be generated by fossil, nuclear or renewable energy to charge those batteries.

The advantage that you have with electric batteries is you try to maintain a more uniform baseload, thus, increasing the efficiency of the system.

Mr. **Fawell**. Thank you.

Mrs. **Lloyd**. Thank you very much.

And thank you, Dr. Berg, and your associates.

We will be submitting questions in writing for the record we would like you to respond to.

Dr. **Berg**. Thank you very much.

Mrs. **Lloyd**. Our next witness is David Webb, Vice-President of the Gas Research Institute.

David is no stranger to the Subcommittee. He has appeared before us many times and we always appreciate his testimony.

STATEMENT OF DAVID O. WEBB, SENIOR VICE PRESIDENT, POLICY AND REGULATORY AFFAIRS, GAS RESEARCH INSTITUTE

Mr. **Webb**. Thank you, Madam Chairman, for those kind words. I am David Webb, with the Gas Research Institute.

Mrs. **Lloyd**. I'm not sure your mike is on.

Mr. **Webb**. I appreciate your kind words. I am here to represent the Gas Research Institute, to make recommendations in conservation and solar and renewables budget for DOE as well as a couple of comments on the fossil energy program.

We co-fund with the Department of Energy research projects in all of these areas and, in addition, we also fund research in all of these areas with manufacturers and other research organizations in the country.

Specifically, the Gas Industry, in developing the recommendations that I represent today, considered three factors.

One was the critical role gas can play in helping to solve some of our environmental problems. The use of our domestic gas research is to reduce a dependence on imported oil, and also the recognition that conservation is really our cheapest source of energy.

In this light, GRI agrees upon a total recommendation of gas-related research in DOE of $125 million, of which $29.5 million would be in the conservation R&D program, $13.4 million in renewable energy R&D programs, and $9.5 million for natural gas vehicle R&D.

Central to this recommendation is out of GRI's total 1990 planned budget of $153 million for R&D, we would be planning to commit $112 million to research in these same program areas and projects.

GRI is an independent, not for profit research organization serving its 304 members and their customers. National energy R&D policy is a major factor affecting our program since we co-fund about $30 million annually with DOE.

So, therefore, actions that Congress takes in the DOE budget does have a direct impact on the GRI budget.

One of the reasons we think that gas research is important is, if you consider how we use energy in this country today, in 1987, the U.S. actual primary energy consumption relied on oil and gas for 63 percent of demand. GRI's projections indicate that in the year 2010, essentially, 20 years from now, we will still rely on oil and gas to provide approximately 55 percent of the energy consumed in this country.

While it is unreasonable to assume that we can become energy-independent, we can reduce our dependence on high levels of oil imports by substituting natural gas for oil. We develop the technology and application where it makes sense.

These includes areas such as cogeneration, many commercial and residential heating and cooling applications, to name a few.

The question might be asked:

Why is this feasible?

Because the natural gas resource base in this country is huge. Recent DOE estimates are that 600 trillion cubic feet of natural gas is still to be developed and found in this country at prices of $3 per million cubic foot, or the equivalent. That is the equivalent of 33 years of annual use at current demand levels.

However, we will not develop these resources if we don't develop the technology to extract them in a cost-effective manner.

If you look at this potential resource and you look at the DOE energy security study that was conducted last March, which concluded that U.S. oil imports will be up to maybe 10 million barrels per day by 1995, which will be over half of our U.S. energy consumption, and then look at the DOE budget request, there seems to be a breakage, if you would, in the logic.

Notwithstanding these DOE findings, the DOE FY-90 budget request is totally inconsistent with this policy with the natural gas potential. Total budget request for gas-related research in all of DOE's fossil and conservation programs is only $32 million, a reduction of 62 percent from the $85 million that Congress appropriated last fall.

Request for unconventional natural gas R&D, which is one of the ones culled out in this study, is only $4.1 million—less than 1 percent of the proposed fossil energy budget.

We think some adjustments need to be made to the budget in order to balance, if you would, policy statements, potential, and the reality of funding research.

Before I discuss the specific program recommendations, I would like to discuss a couple of policy initiatives that GRI supports. The first one is that, in order for natural gas and oil, which currently supplies 63 percent of U.S. energy, to assume a vital and important role in government energy policy, we think it is the time for greater emphasis to be placed on these activities related to natural gas and oil.

GRI supports the gas industry's proposal to create Assistant Secretary for Natural Gas and Oil within DOE, not only to conduct the research but to pull together, if you would, the data bases necessary to see what role gas can actually play in mitigating some of the environmental consequences that we are beginning to recognize as major problems in our country.

GRI also would recommend that DOE and Congress would continue to expand the concept of cooperative R&D ventures. We currently have a cooperative R&D venture in the fossil energy program with DOE, the Bureau of Economic Geology at the University of Texas, and five or six major producing companies, to develop secondary gas recovery; to industry's willingness to invest its own resources—and we're talking about at least 50 percent of the total project funding.

The research is managed and directed in a responsible way to allow the federal government to leverage, if you would, their resources. And it allows the private sector to be involved at the start of a project to affect the technology transfer you were talking about earlier.

So we would recommend that the idea of cooperative R&D ventures in areas such as gas cooling, natural gas vehicles, heat engines and the steel-making processes, which would use gas, be considered.

We are prepared to sit down and talk with DOE and, actually, we have begun conversations with DOE in a couple of these technologies if funding is there to really mount an effective program. In order to attract industry funding partners, we need some kind of a continuity in research level of effort from one year to the next, so that we can make realistic program plans and negotiate some of these specific agreements.

This morning, if I could, I would like to discuss very briefly two of the fossil energy programs, one of which is fuel cells, which really is an energy conservation option, and then the rest of my comments would focus on conservation and renewable energy.

In fossil energy, GRI is recommending $15 million for unconventional natural gas, $4 million of that in the area of Western Tight Sands. We are concentrating our effort on what is called the near-term blanket sands. We have a proposed budget of about $11 million.

In addition, we expect about $4 million from industry. We would recommend that DOE commit $4 million for longer-term research in the lenticular sands formation.

The Eastern Devonian Shales, which underlies 22,000 square miles in the heart of Appalachia, and has estimates of 50–100 trillion cubic feet of economically recoverable gas.

Most of this area is developed and produced by small independents that don't have independent research capability. To cost-effectively produce this gas, we propose that DOE fund $4 million in 1990, primarily looking at directional drilling applications. Meanwhile, GRI's budget in the more near-term aspects would be $5.5 million.

And, finally, in secondary gas recovery, we would recommend $3 million to continue the R&D venture that we started last year with DOE.

The one other fossil energy program is fuel cells, which uses natural gas and electrochemical process to produce electricity and heat. The reason I say this is really a conservation program, it accomplishes very high, overall energy efficiency.

Electric generation efficiency, theoretically, are capable in the 45–60 percent range. If you recycle the waste heat to use it for hot water and space heating, you can get up to 83–85 percent overall energy efficiency.

Two types of advanced fuel cells appear most promising. One is the solid oxide fuel cell. The other is the carbonate fuel cell.

DOE is currently funding three industry teams to develop the carbonate fuel cell and primarily focusing on the cell stack area. We think this effort should be continued and then, at the end of it, they should select the most promising concept to go forward on a joint program with industry. To fund these three projects three industrial teams would take $24 million in 1990. Additionally, in the fuel cell area, we think that solid oxide fuel cell, which is more a long-term, should receive about $10 million. Our budget in solid oxide fuel cells is $3.5 million with another $3.5 million expected from industry.

In the conservation program, we would recommend $10 million for heat pumps; for a typical cold climate residence, the gas heat pump can provide both heat and cooling in a single unit, giving less energy than a conventional 70 percent efficient gas furnace used for heating alone.

Current performance estimates suggest in the heating mode, the heat pump can save up to one-half of the natural gas now used in the conventional furnace.

We are focusing on heat pump technologies most appropriate for a near-term market entry. We think DOE should focus on longer-term, engine-driven concepts in advanced absorbent heat pumps.

Our budget is $11 million in this area in 1990 and we expect to get about $4 million from our manufacturing partners. We would ask that $10 million of the DOE budget would move forward with some of the more advanced concepts.

In the area of gas cooling, using chiller systems, we recommend a total of $8 million. GRI is currently developing advanced cooling, de-humidification systems for supermarkets, the commercial market sector and looking at residential buildings.

One of these projects is an advanced chiller concept conceived at Oak Ridge National Labs. This last year, we negotiated with Oak Ridge and their contractor in this area, and GRI and Trane, which is a major manufacturer of heat pumps, is now in the process of funding about $8 million per year to take that technology and trying to develop the actual prototypes and field test them in actual applications.

Another technology at Oak Ridge is initiating a program of absorbent research with the installation and initial operation of two test loops for cooling.

The objective of this work is to develop a theoretical base that will facilitate the design of absorbers and the applications of enhanced techniques for cooling using gas.

Successful completion of this work would enable us to pick up some of the research with manufacturers and perhaps develop more advanced concepts in cooling.

One of the test loops at Oak Ridge is being used to provide basic information on new absorber design with one of the Oak Ridge subcontractors.

In addition, we do have a joint program underway with Oak Ridge in this development; to provide for benefits, multi-year basic program research is needed at a cost and funding level of about $8 million a year.

Our budget in this same programmatic area is $7 million and we expect to get about $1.7 million from our industrial partner.

In a generic area of research in the conservation program, energy conversion and utilization technology, we would recommend about $8.5 million. Most of this research we think should focus on ceramics. We need to learn how to fabricate ceramics in a cost-effective manner. We need to develop, if you would, some cost-effective manufacturing control technologies.

GRI on its own, in 1986, funded research at Pennsylvania State University. We signed a five-year $10 million contract to set up a center for advanced materials. This center is beginning to provide some basic fundamental knowledge, primarily looking at advanced materials in ceramics.

The DOE work, in addition to ceramics, I think should concentrate on basic combustion phenomena—biocatalysts and other long-term areas.

And we would recommend, like I say, a funding of about $8.5 million. Our budget in this same area in 1990 is going to be about $15 million.

Finally, in the area of renewable energy, we would recommend in the area of biofuels, $5 million. The gas industry believes gas-related R&D in biofuels is being carried out at the Solar Energy Research Institute is in direct support of our industry goals.

We also would recommend continuation of cost-sharing of the community waste project at Walt Disney World where GRI, as well as industrial partners with DOE, are funding SERI to continue this work.

Another significant area of research being done with SERI is methods to remove CO_2 from the air or combustion plant stacks. Alternatives, using either microalgae or metallic catalysts as a scrubbing mechanism to remove CO_2. We think this has quite a bit of potential. And while it is several years away from really knowing if it is going to be cost-effective, the basis for using microalgae is that they are the most productive biochemical factories in the world. They consume seven to 14 times more CO_2 than normal crop plants per land unit area.

We are in the process of sitting down with SERI and trying to negotiate some fundamental research where we would provide some amount of co-funding.

We think DOE should continue to be involved in that at a level of about $5 million.

And, finally, Madam Chairman, one area I know that is not before the Subcommittee today, but there is a potential to address our environmental problems through looking at alternative vehicle fuels, a program you'd have been involved in.

GRI is planning to fund about $5.5 million in 1990 in looking at natural gas vehicles, primarily in the area of diesel engines for inner-city buses and inner-city delivery trucks.

EPA has put out new particulate standards that current diesel engines cannot meet. It is a technology-forcing mandate of 1991. We think a combination of CNG and diesel as a modification first step may allow us to meet the initial standards and develop a CNG engine to go after this market.

We have a partnership with Cummins engine where we are going to be providing about $10 million over three or four years to try to develop these engine options.

We would like for DOE to actually get involved in demonstrating, if you would, CNG vehicles, not just this program, but others, so we can get some empirical data, some real cost data and really see if that's not a viable option in the near-term at least in fleet applications for dealing with some of our major environmental problems.

That completes my testimony. I would be glad to try to answer any questions you might have, and certainly appreciate the opportunity to appear here today.

[The prepared statement of Mr. Webb follows:]

STATEMENT OF DAVID O. WEBB, SENIOR VICE PRESIDENT
POLICY AND REGULATORY AFFAIRS
GAS RESEARCH INSTITUTE
ON THE DOE FY 1990 GAS-RELATED RESEARCH BUDGET
BEFORE THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
SCIENCE, SPACE, AND TECHNOLOGY COMMITTEE
U.S. HOUSE OF REPRESENTATIVES
FEBRUARY 28, 1989

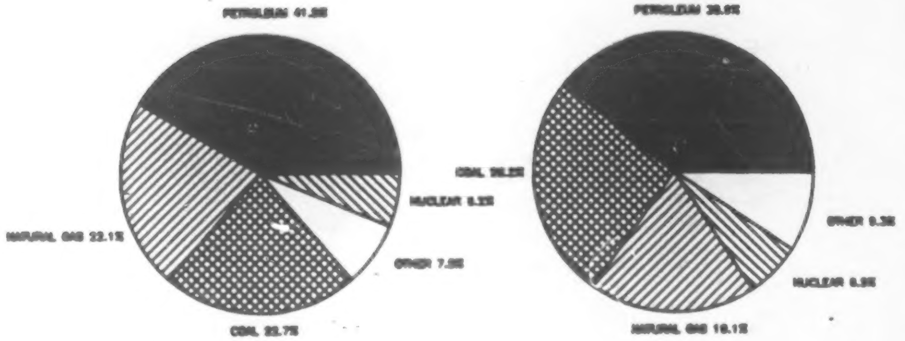
I appreciate the opportunity to appear before you today to present Gas Research Institute's (GRI) recommendations for gas-related research in the Department of Energy's (DOE) FY 1990 Fossil, Conservation, and Solar and Renewables R&D programs. The recommendations reflect the minimum funding required for a viable gas research program in DOE. In developing these recommendations, GRI gave top priority consideration to the need to develop the United States' extensive domestic gas resources to reduce our dependence on imported oil and the critical role gas can play in helping to solve some of our environmental problems. In this light, GRI and the gas industry have agreed upon a recommendation of $125.8 million for gas-related research in DOE's FY 1990 Fossil Energy, Conservation, and Solar and Renewables programs: $73.4 million for fossil energy R&D, $29.5 million for conservation R&D, $13.4 million for renewable energy R&D, and $9.5 million for a natural gas vehicle R&D program. Central to the gas industry's recommendation is that GRI is planning to commit $112.4 million to research in the same programs. Essentially, GRI is proposing that DOE's gas-related budget in FY 1990 approximately equal GRI's research budget in these same program areas.

GRI is an independent, not-for-profit scientific research organization that plans, manages, and finances a cooperative R&D program for the benefit of its 304 members and their customers. The R&D program is implemented through contracts with research organizations, engineering firms, universities, energy companies, and manufacturers. National energy R&D policy is a major factor influencing the R&D program since GRI cofunds and coordinates many of its research projects with DOE. GRI estimates it will coordinate $30 million of research with DOE in gas-related programs in 1990. Therefore, congressional action on the proposed FY 1990 budget has a direct impact on the gas industry's R&D program.

U.S. ENERGY OUTLOOK

The necessity of continuing a viable gas-related federal energy R&D policy becomes evident when we examine where the U.S. is projected to get most of its energy supplies over the next 25 years. U.S. actual primary energy consumption in 1987 relied on gas and oil to meet 63 percent of demand. GRI's projections indicate that in the year 2010, the U.S. will still get 58 percent of its energy from oil and gas. (See Exhibit 1.)

Exhibit 1
U.S. Primary Energy Consumption



1987 ACTUAL PRIMARY ENERGY CONSUMPTION *
(TOTAL 79.3 Quods)

2010 PRIMARY ENERGY CONSUMPTION*
(TOTAL 99.8 Quads)

*Source 1988 GRI BASELINE PROJECTION

Last year the American Petroleum Institute released a report that showed the number of wells drilled in search of oil and gas in 1987 declined more than 10 percent from 1986 levels and more than 60 percent from the drilling peak of 91,000 wells in 1981. By 1986 only 35,000 wells were drilled. U.S. oil production plummeted by 400,000 barrels a day during 1987 to a total of 8.28 million barrels per day. Meanwhile, U.S. consumption increased by 300,000 barrels per day, or by more than 5 percent. The reduced production and increase in consumption are forcing the United States into an even greater dependence on foreign oil, most of which is susceptible to disrupted availability. Imports now account for approximately 43 percent of U.S. consumption. This is the highest oil import level since the end of the 1970s.

While it is unreasonable to assume that the U.S. can become completely energy independent in the near- or mid-term, several options are available to ease the high import level. One obvious option is to substitute natural gas in viable areas that are currently adding to the oil imports. These include natural gas vehicles, combined-cycle power generation, cogeneration, and many commercial- and residential-size heating and cooling applications, to name a few.

The U.S. natural gas resource base is huge. With advances in technology, gas will maintain an important role in a highly competitive future U.S. energy mix well into the next century (See Exhibit 2). This future depends on continuing funding for a viable federal/gas industry research program to produce the technology base necessary to develop plentiful cost-competitive gas supplies and more efficient appliances, equipment, and gas processes. Developing this technology base requires a 10- to 15-year lead time and DOE's and the gas industry's joint effort.

Exhibit 2
Total United States Gas Reserves and Resources 1/

	Technically Recoverable Gas, Tcf	Recoverable Gas by Price	
		$3/Mcf	$3-$5/Mcf
Lower 48 (Conventional)			
Proved Reserves	159	159	--
Inferred Reserves	227	164	18
Gas Resources Associated with Oil	61	30	11
Undiscovered	353	142	87
Subtotal	800	495	116
Lower 48 (Unconventional)			
Gas in Low-Permeability Reservoirs	180	70	49
Coalbed Methane	48	8	4
Shale Gas	31	10	5
Subtotal	259	88	58
Alaska			
Reserves	33	7	0
Inferred	96	5	2
Subtotal	129	12	2
Total	1,188	595	176

1/*An Assessment of the Natural Gas Resource Base of the United States*, prepared by Argonne National Laboratory for U.S. Department of Energy Office of Policy, Planning, and Analysis, May 1988

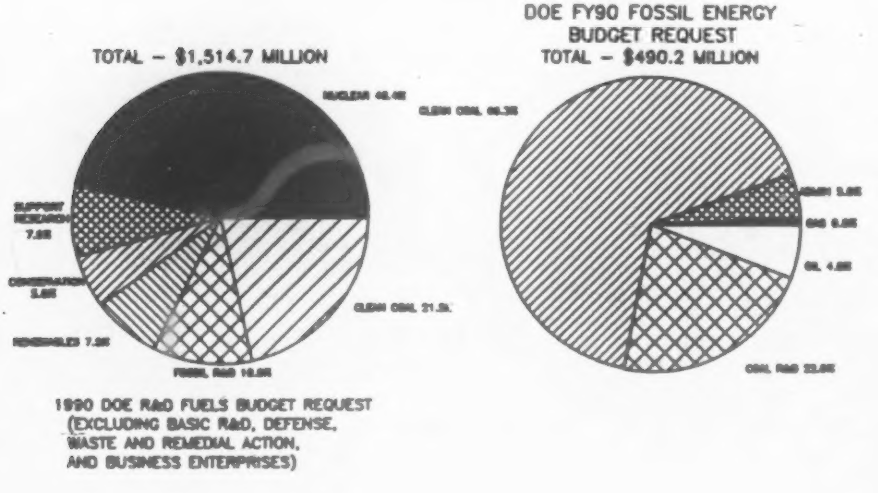
DOE ENERGY POLICY STATEMENTS VS. BUDGET REALITY

In February 1988 DOE announced a major new study to perform a comprehensive assessment of U.S. natural gas reserve potential. In announcing the study, Secretary Herrington stated, "Our growing dependence on imported oil is an Achilles heel." He further stated, "This is an opportune time to reassess the role natural gas can play in displacing imported oil."

The DOE Energy Security Study released last March concluded U.S. oil imports will probably increase substantially by 1995. Projections range from 8 million to 10 million barrels per day. The study also concluded that abundant domestic natural gas is the fuel that is most readily substitutable for oil. The study indicates targeted R&D in unconventional gas is one critical step to reducing U.S. dependence on imported oil.

Also, last May DOE performed a detailed assessment of total gas reserves and resources. The results (see Exhibit 2) show that over 1000 Tcf of gas is technically recoverable with approximately 600 Tcf recoverable by using advanced technology at prices of $3/Mcf. Included in this recoverable gas is 85 Tcf in unconventional reservoirs. Notwithstanding these DOE study findings, the DOE FY 1990 budget request is totally inconsistent with policy and the gas potential. The total budget request for gas-related research in DOE's Fossil and Conservation programs is only $32.24 million, a reduction of 62 percent from the $85.5 million Congress appropriated last fall. The request for unconventional natural gas R&D is only $4.1 million, less than 1 percent of the proposed Fossil Energy budget. The budget does not support the policy of allowing gas to play an important strategic role in reducing U.S. dependence on oil imports and solving environmental concerns. (See Exhibit 3.)

Exhibit 3
DOE's Program Is Out of Balance When Compared With
the Present and Future Energy Needs of the Nation



1990 DOE R&D FUELS BUDGET REQUEST
(EXCLUDING BASIC R&D, DEFENSE,
WASTE AND REMEDIAL ACTION,
AND BUSINESS ENTERPRISES)

PROPOSED JOINT DOE/GAS INDUSTRY GAS RESEARCH PROGRAM

An expanded joint effort between the gas industry and DOE is needed to ensure a stable, reliable energy mix for this nation's security. To maintain this joint effort, GRI recommends $125.8 million for DOE's gas-related research budget in Fossil Energy, Conservation, and Solar and Renewables programs. In many cases, these projects are being coordinated or cofunded with gas industry funding. GRI encourages greater use of cooperative R&D ventures to conduct much of this research especially in CNG vehicles, geosciences, unconventional natural gas, and residential/commercial space heating. Congress has recognized the need for a viable DOE gas-related program and has appropriated approximately $100 million each year for these DOE programs. (See Exhibit 4).

Exhibit 4
Gas-Related Research Recommendations for DOE FY 1990 Fossil Energy and Conservation Programs
($ Millions)

	FY 1988 Approp.	FY 1989 Approp.	FY 1990 Gas Industry Recommend.	GRI Planned Budget 1990 1/
Fossil Energy				
ARTD (Gas-Related)	$ 6.0	$ 6.00	$ 6.0	$11.4
Fuel Cells (Gas-Related)	20.5	17.03	36.5	3.5
Coal Gasification	24.2	23.82	5.9	1.9
Combustion Systs. Emission Control	0.0	0.00	2.0	5.2
Heat Engines (Gas-Fueled)	3.0	3.00	8.0	5.5
Unconventional Natural Gas	10.9 2/	12.38 2/	15.0	36.8 3/
Fossil Energy Subtotal	**$64.6**	**$62.23**	**$73.4**	**$64.3**
Conservation R&D				
Heat Pumps & Prime Movers	$ 5.8	$ 6.600	$10.0	$11.3
Industrial Cogeneration	5.0	4.600	0.0	0.0 4/
ECUT (Gas-Related)	8.9	13.420	8.5	15.5
Indoor Air Quality/Bldg. Systs. Research	1.9	1.390	3.0	4.2
Desiccant Systems	0.7	1.265	8.0	6.9
Natural Gas Vehicles	0.0	0.000	9.5	6.4
Conservation Subtotal	**$22.3**	**$27.275**	**$39.0**	**$44.3**
Solar and Renewables R&D				
Biofuels (Gas-Related)	$ 8.5	$ 6.5	$ 5.0	$ 3.8
Geopressured Resources	5.0	6.0	8.4	0.0
Solar and Renewables Subtotal	$13.5	$12.5	$13.4	$ 3.8
Total—Fossil Energy, Conservation, & Renewables	$100.4	$102.01—	$125.8	$112.4

1/Preliminary estimate--not yet FERC-approved

2/Includes geoscience activities

3/Includes $3.6 million for geosciences

4/Heat Pumps & Prime Movers budget includes $2.5 million for Industrial Cogeneration

The GRI planned budget for 1990 in Exhibit 4 reflects only a partial picture of the gas industry's R&D effort. GRI's total 1990 R&D budget is $153.5 million. The R&D program includes supply, end use, gas operations, and crosscutting research (see Exhibit 5).

Exhibit 5
GRI R&D Programs

	1989		1990*	
	Budget ($M)	Percent	Budget ($M)	Percent
Supply Options	39.97	27.2	44.52	29.0
End Use	80.95	55.2	81.79	53.3
Gas Operations	20.28	13.8	21.59	14.1
Crosscutting Research	5.50	3.7	5.60	3.6
	146.70	100%	153.50	100%

*Preliminary estimate--not yet FERC-approved

GRI's R&D program helps to assure, both now and in the future, the widest use of natural gas that is consistent with a least-cost energy strategy. Major emphasis is placed on the development of technologies that have the potential to increase the efficiency of using natural gas in existing applications, and that are critical to new, cost-effective applications in which economic or other advantages can be identified. More specifically, GRI's program is designed to:

1. Decrease the cost of producing and delivering gas;

2. Enhance the role of gas in providing least-cost energy services, recognizing the importance of maintaining and increasing the superior quality, convenience, safety, and reliability of gas energy service at competitive prices;

3. Facilitate the transfer of new technology and technical and scientific information to the gas industry and its customers; and

4. Stimulate innovation in gas-related technologies through a mission-oriented basic research program.

RECOMMENDED GAS POLICY INITIATIVES

1. Establish an Office of Assistant Secretary for Natural Gas and Oil

In order for natural gas and oil to assume a more vital and important role in government energy policy, it is time for greater emphasis to be placed on activities related to natural gas and oil. GRI supports the gas industry's proposal to the Administration to create the post of Assistant Secretary of Natural Gas and Oil within DOE. This official would have overall responsibility for coordinating gas and oil research and policy within DOE and the government as a whole.

Natural gas and oil provide over 65 percent of current U.S. energy and are projected to provide over 50 percent of U.S. energy in 2010. Yet the DOE Fossil Energy budget devotes less than 6 percent of its funding to R&D for these two resources. We must have a better balance between U.S. energy use and energy R&D funding if the U.S. is ever going to develop a rational energy policy. The establishment of an Office of Assistant Secretary for Natural Gas and Oil would demonstrate a commitment to a rational energy policy and would promote the visibility and public understanding that gas and oil issues require.

2. Increase Geoscience Funding

GRI believes that in addition to increasing traditional energy R&D dollars, DOE needs to reevaluate its basic energy research goals and address a hydrocarbon geoscience research program. The increased oil and gas budgets for geoscience-type research is a step in the right direction. However, more needs to be done.

For the next 25 years, GRI estimates that oil and gas will provide over 50 percent of U.S. energy needs. Almost all the domestic oil and gas production by 2010 will have to come from fields and reservoirs not yet discovered and/or enhanced recovery technologies to produce the nearly two-thirds of the oil currently left in the ground. Whatever is not produced from these domestic discoveries will have to be satisfied by imported oil, primarily from OPEC nations.

Recent DOE actions to establish a geoscience office in Fossil Energy are encouraging. However, funding is required to implement an R&D program. GRI recommends DOE commit a total of $20 million in FY 1990 with $10 million designated for gas-specific research. This funding should be established as a separate line item in Fossil Energy.

3. Continue and Expand Cooperative R&D Ventures

GRI encourages DOE and Congress to continue and to expand the concept of cooperative R&D ventures. We believe the current cooperative R&D venture with GRI, the State of Texas Bureau of Economic Geology, and DOE in secondary gas recovery is working well. The most effective technology transfer occurs when industry is involved early and substantially in a research and development effort. The more directly the research agenda is guided by the companies' own technological and economic needs, the more effective transfer is likely to be.

While the cooperative venture concept is still a relatively new approach to government-industry financial partnerships, it is one that gives the private sector greater incentive to carry out research programs that are responsive to its R&D needs. Through industry's willingness to invest its own resources (at least 50 percent of the project funding), the research is managed and directed in a responsible way. In short, a joint R&D venture offers a relatively low-cost route to innovative technology through pooling government and industry resources.

GRI particularly recommends cooperative R&D ventures in gas cooling technologies, geosciences, unconventional natural gas, natural gas vehicles, and heat engines. GRI is prepared to initiate discussions with DOE on cooperative R&D ventures in these technologies if Congress provides funds.

RECOMMENDED DOE FY 1990 GAS-RELATED RESEARCH

Budget request levels continue to be far below what is necessary to conduct critical gas-related R&D in fossil, conservation, and renewable energy, and Congress has consistently increased these budget areas to provide a consistent funding level for ongoing research. In order to attract industrial funding partners in this research effort, it is necessary to maintain a continuity in funding and support for these ongoing programs. In its recommendations for gas-related research, GRI and the gas industry have, for the most part, requested a maintenance of ongoing programs supported by Congress in the past. But as public attention focuses on environmental issues such as acid rain and global warming, it is time to increase R&D in those areas that address environmental needs. The gas industry, through GRI, is investigating technologies to reduce pollution and the greenhouse effect both through supporting technology development and by conducting generic environmental and safety studies to assess actual and potential environmental implications for existing and emerging gas technologies. Therefore, some increase over past years recommendations is shown in the gas industry's recommendation for FY 1990 for fuel cells, natural gas vehicles, and heat engines. This increase is tied to technologies which address environmental concerns.

Following is a recommendation for specific programs of particular interest to GRI.

FOSSIL ENERGY

	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
Western Tight Sands	$3.3 Million	$3.325 Million	$4.0 Million

Significant amounts of potentially recoverable natural gas exist in low-permeability sandstone formations located in sedimentary basins throughout the United States. Current information indicates that the total amount of economically recoverable gas from tight sands could be in excess of 500 Tcf. However, a combination of technical limitations and economic constraints prevent the widespread commercial exploitation of these resources. It is estimated that the development of advanced technologies and practices applicable to tight gas sands could provide an additional 200 Tcf of cost-competitive gas over what is recoverable with the present state-of-the-art technology.

Gas-bearing tight sands occur in the form of blanket-type and lenticular formations. In both types, the effects of a variety of interdependent parameters are still unknown, and consequently, the gas recovery rate and active reservoir life for a given field remain uncertain. To permit low-cost exploitation of the full potential of the tight sands resource base, the following specific technological issues need to be addressed:

1. Determine the relationship between geologic and engineering parameters;

2. Further characterize tight sands gas reservoirs and improve resource estimates;

3. Identify the parameters critical to formation evaluation and gas production;

4. Understand more clearly the mechanisms of hydraulic fracture propagation and control;

5. Diagnose fracture shape and downhole conditions using surface parameters;

6. Provide real-time fracture treatment design changes; and

7. Apply advanced technologies to presently noncommercial areas.

Geotechnical and economic analyses have demonstrated that blanket-type formations are more amenable in the near term because the geologic environments in which they exist are less complex than the environments associated with lenticular formations. Therefore, GRI has concentrated its efforts in the near-term aspects of blanket-type formations such as resource characterization, formation evaluation, fracture diagnostics, and real-time analysis development. In addition, in 1989 GRI plans four staged field experiments to validate technologies developed in this project area. GRI's planned 1990 budget for tight gas sands is $10.0 million. In addition, it is expected that industrial partners will contribute another $4.25 million. GRI recommends that DOE commit $4.0 million for longer-term research in the lenticular formations.

	FY 1988	FY 1989	FY 1990
Eastern Devonian Shales	Appropriation	Appropriation	Recommendation
	$2.3 Million	$3.075 Million	$4.0 Million

The large eastern Devonian gas shales resource base underlies approximately 175,000 square miles of the Eastern United States. Current information indicates that the gas-in-place is approximately 2000 Tcf; however, large uncertainty exists regarding how much of that resource may be recoverable. There is approximately 120 Tcf of gas-in-place in a drillable area of 22,000 square miles in the heart of the Appalachian Basin, and projections indicate that up to 50 Tcf of gas may be technically recoverable.

In general, two major factors constrain present-day exploitation of this resource: (1) the inability to predict with confidence the gas production rates that will be obtained in wells drilled outside of historical production areas, and (2) the inconsistent response of formations to currently employed stimulation practices. Because most of the producers in the Appalachian Basin are small independents, they cannot afford to conduct the comprehensive R&D required to understand and solve these problems.

Barriers to economic production of natural gas from Devonian shales include:

1. Inadequate understanding of factors that control the flow of gas from Devonian shale formations to the wellbore;

2. Lack of effective exploration rationales to identify geographic areas and stratigraphic zones with highest production potential;

3. The need for improved diagnostic methods to assess the potential of productive zones;

4. Inadequate understanding of shale gas reservoir dynamics; and

5. Lack of generally effective stimulation techniques.

Economic exploitation of the full resources hinges on development of improved techniques and technologies for overcoming these limiting factors.

GRI's program in eastern Devonian shales includes reservoir evaluation, recovery enhancement methods, geologic production controls, and development of a resource well information data base. GRI's planned 1990 budget for eastern Devonian shales is $5.5 million with an additional $1.1 million in industrial funding expected. The gas industry recommends a total of $4.0 million for DOE research of eastern Devonian shales.

Secondary Gas Recovery	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
	$2.5 Million	$2.5 Million	$3.0 Million

A significant quantity of natural gas requiring minimal exploration and in close proximity to gathering systems and pipelines is known to exist in currently producing and abandoned wells and fields. These potential reserve additions consist of (1) bypassed gas in currently producing or temporarily abandoned wells, (2) reservoir compartments in existing fields, and (3) gas trapped by the encroachment of water in water-drive reservoirs.

To ensure the timely development of technologies for near-term production of bypassed gas and gas from undiscovered reservoir compartments in developed fields, the following specific technological issues need to be addressed: (1) improved understanding of geologic environments and characteristics of gas fields to allow for more accurate resource identification and estimates, (2) provision of an accurate methodology for cased-hole formation evaluation, and (3) development of in-field reexploration rationales based on a better understanding of reservoir heterogeneities. By addressing these issues, gas producers can exploit appropriate elements of the conventional resource base in the near term at market-clearing prices. Over the longer term, application of these technologies can increase gas reserves and deliverability of low-cost gas through more effective and efficient development of fields yet to be discovered.

In addition to bypassed gas and gas from undiscovered reservoir compartments in developed fields, an estimated 500 Tcf of technically recoverable natural gas (50 Tcf of which is estimated to be economically recoverable) exists in water-drive reservoirs in the form of trapped gas. The gas becomes trapped as a result of the encroachment of water into production wells and the inability to maintain low reservoir pressure due to high water influx into the reservoirs. Once high levels of water production are reached, the traditional production practice is to plug and abandon the affected gas wells and ultimately the gas field. Recent data have indicated that the recovery efficiencies for the prolific water-drive gas reservoirs along the Texas-Louisiana Gulf Coast are now recognized to be 50 percent or less.

Specific technological issues that need to be addressed include:

1. Improving the understanding of geologic environments and characteristics of gas fields to allow for resource identification and estimates;
2. Providing a methodology for cased-hole formation evaluation; and
3. Developing in-field reexploration rationales based on an understanding of heterogeneities.

Currently, GRI's program addresses resource characterization, coproduction of trapped gas and water, and brine treatment and control. An initiative undertaken in 1988 was research into the undiscovered reservoirs in known fields. This Secondary Gas Recovery program is cofunded with the Department of Energy, GRI, the State of Texas Bureau of Economic Geology, and producers under a cooperative R&D venture.

GRI's planned 1990 budget for secondary gas recovery is $6.7 million with an additional $3.0 million expected from industry. The recommendation to DOE is $3.0 million.

Underground Coal Gasification	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
	$2.825 Million	$1.371 Million	$2.5 Million

Underground coal gasification offers a method for recovering coal resources, without the need for mining, by gasifying the coal in-place underground. Oxygen, in conjunction with steam, is injected into an underground coal bed to drive and control the gasification reactions. As a potential source of cost-competitive pipeline-quality gas, in situ coal gasification may be able to tap those vast coal deposits that would not normally be economically recoverable using existing or anticipated strip- or deep-mining methods. Underground coal gasification is, therefore, applicable to a different coal resource base than surface gasification. In comparison with present-day surface gasification processes, underground technology offers a projected 15 to 35 percent cost savings as well as possible environmental and safety advantages.

At the present time, underground coal gasification must be classified as a high-risk, advanced technology, but one with very high payoff potential. This high payoff would be due at least in part to the very large potential resource base to which this technology can apply. DOE has estimated that, of the current 6.4 trillion tons of domestic coal resources, only about 0.5 trillion tons are currently economically recoverable by existing surface- and deep-mining techniques. Underground coal gasification could potentially utilize about 1.8 trillion tons, producing more that 1000 Tcf of substitute natural gas, even if only 10 percent of this resource is suitable for gasification.

Major challenges confronting successful development of in situ gasification include: (1) the verification of low-cost, reliable, reproducible methods for providing a pathway linking injection and production wells; (2) control of the combustion front and gas quality; and (3) prediction and mitigation of subsidence potential and other environmental impacts. In particular, additional R&D is needed to further prove the applicability and reliability in the field of the low-cost, controlled-retracting-injection-point (CRIP) concept developed by Lawrence Livermore National Laboratories. This concept provides the capability of reducing cavity and roof interactions (which can decrease gas quality during the burn) by controlled relocation of the burn cavity within the coal seam when cavity/roof interactions begin. The first large-scale test of the CRIP technology--a 30-day test at Centralia, Washington, under DOE and gas industry sponsorship--was successfully completed in 1983. A large-scale test (conducted for 100 days by GRI as the head of an industry consortium in conjunction with DOE at Hanna, Wyoming, during late 1987 and early 1988) assessed the technology further. The test results defined the viability of the CRIP process for the cost-effective recovery of subbituminous unmineable coals in flat coal seams.

Continued DOE support is needed to do post-burn coring and generic environmental work at the Rocky Mountain I site, analysis of RMI data by Lawrence Livermore National Laboratory, completion of treatment of the abandoned Hoe Creek UCG site, and planning for follow-on UCG environmental research.

GRI's 1989 budget for underground coal gasification is $725,000, and GRI's planned budget for 1990 is $450,000. The recommendation for DOE's FY 1990 budget is $2.5 million.

Fuel Cells (Gas-Related)	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
	$20.45 Million	**$17.034 Million**	**$36.5 Million**

A fuel cell uses natural gas in an electrochemical process to produce electricity and heat. This is accomplished with very high overall energy efficiency, good reliability, low noise, and virtually no pollutants. The gas utility industry, in cooperation with other parties, has supported the development of onsite phosphoric acid fuel cells for the past two decades as alternatives to existing prime-mover-powered cogeneration systems for use in commercial and industrial cogeneration applications. Two developments have made clear that the technology base for an early-entry fuel cell power plant is presently well defined: (1) the successful field testing (from 1983-1986) of 46 40-kW fuel cell systems and (2) the decision by the participating manufacturer to commercially offer larger phosphoric acid fuel cell (200-kW) power plants for delivery starting in 1990 or 1991. R&D is still warranted, however, to reduce the capital cost and increase the performance and durability of phosphoric acid fuel cell systems to levels acceptable for commercial viability. Early-entry systems of this type will serve to introduce the fuel cell concept to a wide range of potential users.

Advanced fuel cell technology, currently being addressed by several organizations worldwide, offers three important operating benefits compared with phosphoric acid fuel cells: (1) electrical efficiencies of 45 to 63 percent (compared with 36 percent for phosphoric acid fuel cells), (2) higher temperature operation (1300°-2000°F vs. 400°F) offering higher-quality thermal energy, and (3) ability to use natural gas directly without extensive reformer equipment. Two types of advanced fuel cells appear promising: the solid oxide (ceramic) fuel cell (SOFC) and the carbonate fuel cell (CFC). SOFC technology is promising because of its potential for high-power-density cell stacks, its solid state construction which eliminates the liquid electrolyte, and its potential as a simpler and less expensive system than the carbonate type. Major R&D efforts are needed, however, on cell fabrication technology and durability before detailed SOFC system development can be undertaken.

Research on CFC technology is being conducted by several organizations in the United States and Japan for use primarily on central-station electric generation. GRI has monitored the progress being made in this research, especially with regard to potential application of carbonate technology in an onsite cogeneration system. Although the development of CFCs has proceeded further than solid oxide systems, major development efforts are still needed in the cell stack area (power section) before the CFC can be commercialized. These efforts include activities that have long development times and represent major technological hurdles: electrode performance and durability, electrolyte management, corrosion, thermal cycling, integration of stack components, and improved fabrication technologies.

GRI's planned 1990 budget for fuel cell activity is $3.5 million with an additional $3.4 million from industrial partners. The gas industry recommends a DOE budget of $36.5 million for molten carbonate and solid oxide fuel cells and for a generic program in phosphoric acid fuel cells.

CONSERVATION

Heat Pumps	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
	$5.8 Million	$5.8 Million	$10.0 Million

For a typical cold-climate residence, the gas heat pump can provide both heating and cooling in a single unit using less energy than a conventional (70-percent-efficient) gas furnace would use for heating alone. Current performance estimates suggest that in heating, the gas heat pump could save up to one-half the natural gas now used by a conventional furnace or one-fourth the energy used by a high-efficiency (90-percent-efficient) furnace. The gas heat pump can also be a cost-effective alternative to electric cooling in regions where the cooling load is significant and the electric-to-gas price difference is high. In addition, the gas heat pump could fill the summer "valley" for gas utilities while also substantially reducing summer peak demands for electricity, thereby favorably impacting operating costs for both gas and electric utilities.

Development of the gas heat pump, however, faces several major challenges. Initial cost of the gas heat pumps being developed by GRI is estimated to be up to 15 percent higher than that of other space-conditioning options such as electric heat pumps or combination gas-furnace/electric-air-conditioning systems. Consumers are still sensitive to the first-cost difference among competing products even though they are increasingly aware of economic decision criteria such as payback and return on investment. In selected applications, the lower operating cost of the gas heat pump can offset its high first cost; however, the economic merit of the gas heat pump will be very sensitive to the magnitude of heating and cooling loads as well as the difference in gas and electricity prices.

Achievement of gas heat pump targets for life-cycle cost and payback requires substantial technical advancements, particularly in engine and/or advanced absorption technologies, to improve first cost, efficiency, life, maintenance frequency, and maintainability.

GRI's program is focused on developing gas heat pump technologies most appropriate for near-term market entry, with active support and participation by both the HVAC manufacturers and gas utilities in the R&D activity as early as possible. Based on past GRI efforts, the technologies now considered most promising for near-term market entry include: (1) a dual cycle absorption heat pump using existing fluids with an advanced heat-exchange subsystem, (2) an engine-driven heat pump using available internal combustion engine technology modified for high reliability and long life, and (3) an advanced adsorption heat pump.

GRI's planned 1990 budget for residential and commercial heat pumps is $11.3 million with an additional contribution of $4.3 million expected from industrial partners. A budget of $10 million is recommended in DOE's technology and consumer products budget.

NG Cooling/Desiccants	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
	$ 70,000	$1.265 Million	$8.0 Million

In cooling applications a variety of technical challenges must be overcome to make more competitive technologies available. High latent-load applications and air-conditioning in high ambient humidity areas represent opportunities for desiccant-based dehumidification and cooling systems. Needed desiccant improvements include higher performance, reduced equipment size, and improved understanding of the capability of desiccants to remove airborne pollutants as well as moisture.

In desiccant technology, warm air from a gas burner is used to dry or regenerate the desiccant material which absorbs or removes moisture and thereby handles the latent cooling load. In buildings where moisture control and air quality are essential, desiccant cooling cycles offer a unique opportunity to attack moisture problems as well as air cleanliness.

GRI is currently developing advanced cooling/dehumidification systems for supermarkets, other commercial buildings, and residential buildings using both gas-regenerated desiccant and an electric air conditioner to provide optimum cost-effectiveness and comfort.

In another technology, Oak Ridge National Laboratory (ORNL) has initiated a program of absorber research with the installation and initial operation of two test loops for cooling: one for ammonia-based fluid systems and the other for water-based systems. The objective of this work is to develop a theoretical and experimental knowledge base that will facilitate the design of absorbers and the application of enhancement techniques. Successful completion of this work is expected to enable the design of more compact, more effective, and lower-cost absorbers and to reduce required R&D time and costs.

The absorber is a key component of absorption heat pumps and chillers. Absorption chillers have been in use for space conditioning applications for several decades. These devices have favorable energy use characteristics and economics when operating on waste heat, but are generally more expensive than electric chillers when operating on natural gas. A new generation of gas-fired absorption chillers is now being developed with support of organizations that include DOE, GRI, and a few gas utility companies. These systems have potential for operation at twice the energy efficiency of conventional chillers; moreover, most of these systems can be designed as heat pumps that provide heating and/or cooling and can operate in the heating mode at twice the efficiency of the best furnaces and boilers. Advanced absorption chillers and heat pumps, if successfully developed and commercialized, have the potential to provide space conditioning for residences and commercial buildings at lower cost and reduced energy consumption compared with existing equipment. They will also provide seasonal load leveling for both gas and electric utilities.

The expanded use of absorption systems will also produce environmental benefits. In addition to reducing the national use of fossil fuels, their use of natural gas has the benefit of producing low CO_2 emissions per unit of energy consumed. Also, absorption systems do not depend on the use of ozone-layer-depleting chlorofluorocarbon refrigerants.

The absorption process is basically the absorption of a vapor, such as ammonia, into a liquid solution of water and dissolved ammonia. Heat is liberated in the absorption process and the solution must be cooled to keep the process going. The heat picked up by the coolant is used either to provide space heating or it is used beneficially elsewhere in the machine. While this phenomena does not sound complex, it involves simultaneous heat and mass transfer, a process that is not well understood scientifically. As a consequence, absorbers in use today have mostly been designed using a costly and time-consuming procedure. Moreover, the absorber is typically one of the largest and most expensive components of the system.

The development of the new advanced absorption machines requires the development of absorbers operating in new temperature and pressure ranges and possibly with new fluids. Time and costs for this work can be reduced with information gained from ORNL absorber research, and a better result can be expected.

One of the ORNL test loops is now being used to provide basic information on a new absorber design to one of ORNL's subcontractors developing an advanced absorption heat pump. In addition, a joint GRI/ORNL program is under development. However, to provide the full potential benefit of this research, support for a multiyear basic program is needed.

GRI's planned 1990 budget for desiccant cooling systems is $6.9 million with an additional $1.7 million expected from industrial partners. A budget of $8.0 million is recommended for DOE to address advanced cooling systems.

	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
Energy Conversion and Utilization Technology (Gas-Related)	$8.9 million	$7.0 million	$8.5 million

The advantages of structural ceramic materials versus metal alloys are well documented. Because ceramics are lightweight, retain their strength at high temperatures, and have high corrosion and wear resistance, they can increase complexity and reduce maintenance through the use of noncooled components, and they can increase equipment life due to improved corrosion and wear resistance. To help ensure that these potential benefits of ceramic materials are fully realized; however, R&D is needed to address several technical issues that have impeded wide market penetration.

The key elements used in ceramics manufacture--aluminum, silicon, zirconium, titanium, carbon, nitrogen, and oxygen--are relatively abundant and inexpensive. This is in marked contrast to the uncertain supply and cost outlook for some strategic metals common in the manufacture of high-temperature metallic components. However, labor-intensive fabrication techniques geared toward limited-volume production of ceramics have resulted in high component and system costs. Reliability and cost are particularly important issues in the production of large components with variable geometries. Research is needed to develop more systematic fabrication techniques for the forming and sintering of more reliable ceramic parts, and reproducible and cost-effective manufacturing and quality control techniques are needed for the large-scale production of reliable ceramic materials and components.

In 1986 GRI helped establish the Center for Advanced Materials (CAM) at Pennsylvania State University and signed a five-year, $10 million agreement to fund the center. The CAM serves to consolidate and coordinate the necessary resources and expertise to provide advanced materials suppliers, manufacturers, and end users with (1) concise, targeted information on advanced materials property and performance data, (2) material and component analytical and engineering services, and (3) applied material research to facilitate the use of advanced materials as accepted engineering materials. Efforts at the CAM provide a mix of near-term and long-term R&D targeted toward the needs of the gas industry, equipment manufacturers, and end users. The CAM capitalizes on coordinated funding from other sources and utilizes existing facilities and broad expertise to more cost-effectively achieve R&D goals.

In addition to ceramics work, important crosscutting research in the areas of combustion, biocatalysis, and tribology provide invaluable information and technological advancement for the gas industry.

GRI's planned 1990 budget in these areas totals approximately $15.5 million with an additional $4.7 million expected from industrial partners. The recommendation for gas-related research within the ECUT programs is $8.5 million.

	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
Natural Gas Vehicles	$ 0	$ 0	$9.5 million

In the late 1970s, increased gasoline and diesel fuel prices and related concerns about gasoline rationing generated renewed worldwide interest in natural gas as an alternative to gasoline and diesel fuel in stationary and mobile engines. Continued concern over the reliability of imported petroleum supplies also prompted several domestic and foreign automobile manufacturers to evaluate a broad range of fuel alternatives including natural gas. While the competitiveness of natural gas vehicles (NGVs) is extremely sensitive to assumptions about capital costs, fuel costs, and resale value, the potential market for these vehicles is appreciable. Several analyses of both vehicle usage patterns and existing institutional barriers to increase utilization of natural gas fuel have helped identify certain fleet vehicles as the most promising near-term application for the large-scale penetration of NGVs.

Recent environmental concerns have been an issue as well. The Environmental Protection Agency issued new standards for vehicles that immediately affect heavy-duty diesel vehicle fleets. These standards are "technology forcing" regulations, specifically, the 1991 limit for transit bus diesel particulate emissions of 0.1 G/BHP-HR (grams per brake horsepower-hour). This is beyond the state of the art for conventional diesel technology. A demonstration program would be beneficial to determine the contribution a natural gas vehicle or natural gas/diesel vehicle would make towards meeting EPA's regulations.

Environmental emissions from NGVs will depend on the degree to which engine calibration and hardware configurations are optimized to utilize natural gas. Currently, available exhaust emissions data are quite inconclusive with respect to the environmental benefits of natural gas as a vehicle fuel versus alternatives such as gasoline and methanol. This is particularly true of compression-ignition (diesel) engines converted to use natural gas and late-model spark-ignition vehicles using computer-controlled emission systems. There is a need for a comprehensive NGV emissions data base to help establish engine conversion kit research goals and to ensure that this technology remains an environmentally acceptable application of natural gas.

There is little data available today by which to determine the contribution natural gas/diesel engines might make in meeting current and future EPA standards. GRI is currently developing a retrofit kit and compiling some preliminary data to help determine the impact of natural gas use to meet these standards and to be used as a basis for demonstration of natural gas/diesel in two-stroke diesel engines which make up about 95 percent of the heavy-duty public transit vehicles. It is recommended that DOE address the cost of the vehicle conversion and the compression stations. Testing should be done in both northern and southern climates with six to ten heavy-duty vehicles in each station. A mixture of urban expressway and intracity buses is required with a minimum operation of 12 to 18 months.

GRI is currently funding research in advanced compressed natural gas (CNG) fueling system developments and enhanced CNG storage systems. In addition, GRI and a manufacturer are working on a cost-effective retrofit kit to permit dual-fuel or spark ignition natural-gas-only operation of existing two-stroke diesel transit buses to meet 1988 EPA standards. To meet the 1991 EPA standards, GRI is developing two natural gas engines--one a two-cycle, the other a four-cycle engine--to enable transit buses to comply with the regulations.

GRI's planned 1990 budget for natural gas vehicle research is $6.4 million with an additional $525,000 expected from industrial partners. A budget of $9.5 million is recommended for DOE in FY 1990 to pursue the natural gas vehicle technology.

SOLAR & RENEWABLES

Biofuels (Gas-Related)	FY 1988 Appropriation	FY 1989 Appropriation	FY 1990 Recommendation
	$8.5 Million	$6.5 Million	$5.0 million

The gas industry believes the gas-related research and development in biofuels being carried out at the Solar Energy Research Institute is in direct support of our industry's goals. Of particular value is the biotechnology process of anaerobic digestion of municipal solid waste which includes genetic and other improvement of biological organisms and development of innovative reactor design concepts. Continuation of cost sharing of the Community Waste Project at Walt Disney World, Florida, by the GRI and the DOE through the Solar Energy Research Institute is encouraged. This project has resulted in the construction and operation of the 1200 gallon digester at the experimental test unit (ETU). Work in the future should be directed to methods to decrease solids residence times, increase solids concentrations, and understand and control the biological populations in digesters. This work has the potential to provide technology that can produce methane for less than $3.50/MMBtu.

Another significant area of research at the Solar Energy Research Institute is methods to remove CO_2 from the air or from combustion plant stacks. Novel alternatives are under development either using microalgae or methyl catalysts as a scrubbing mechanism to remove CO_2 and convert it to fuels such as gasoline or methanol. The basis for using microalgae is that they are the most productive biochemical factories in the world--they consume 7 to 14 times more CO_2 than crop plants per unit land area. Two, one-quarter acre size microalgae ponds are already in operation at an outdoor test facility in New Mexico. Carbon dioxide in a processed combustion plant flue gas could be directly injected into pond water. Trapping efficiency is estimated to be at least 50 to 80 percent with current technology. The microalgae synthesize oils from the CO_2 and other nutrients and these oils can be converted to gasoline for fuel. Metal catalysts work by first adsorbing CO_2 from the atmosphere or from flue gases and then through a three-step process converting it to methanol. This research involves the synthesis of new metal catalytic compounds to remove CO_2 from air with high efficiency. In one year, compounds have been synthesized that are capable of being four times as efficient as existing systems. Excellent progress has been made on two of the three steps in the development of methyl catalysts to convert CO_2 to methanol. The third step is vital, and funds should be made available to undertake work in this area as well as improve further the other steps of the process. This approach has significant promise to aid in the greenhouse problem.

These projects have been funded by the Department of Energy but at levels well below those needed to make timely advances to benefit industry. Therefore, it is recommended that the FY 1990 biofuels budget be increased to $25 million with $5 million for gas-related research and development.

GRI's planned 1990 budget for biofuels is $3.8 million with an additional $550,000 expected from industrial partners. The recommendation for DOE's contribution to continue these program is $5.0 million.

SUMMARY

GRI recommends that the Department of Energy continue to fund a viable, consistent gas-related research program that adequately addresses the long-term needs of this nation's energy supply and environmental concerns. A total of $125.8 million would continue the programs Congress has already approved in past years and would address new environmental technologies (see Exhibit 6). We believe this budget recommendation is consistent with the realities resulting from the large budget deficit, the need for a balanced energy policy and the need for additional environmental research. It should be noted that the gas industry is funding near-term research in these program areas with a GRI R&D budget of approximately $112 million.

These central themes of funding adequate, long-term gas research in DOE while GRI funds near-term research and of strengthening the oil- and gas-related geosciences and environmental programs are sound national energy policies that Congress should implement.

Exhibit 6
Recommended DOE Gas-Related Budget for FY 1990 for Fossil, Conservation, and Renewables R&D ($ Millions)

	FY 1987 Approp.	FY 1988 Approp.	FY 1989 Approp.	FY 1990 Gas Industry Recommend.
Fossil Energy				
ARTD	$ 8.6	$ 6.0	$ 6.00	$ 6.0
Fuel Cells (Gas-Related)	14.9	20.5	17.03	36.5
Heat Engines (Gas-Related)	0.0	3.0	3.00	8.0
Surface Coal Gasification	24.6	21.4	22.45	3.4
Unconventional Natural Gas	8.1	10.9 1/	12.38 1/	15.0
Underground Coal Gasification (Technology Base)	2.4	2.8	1.37	2.5
Subtotal	$58.6	$64.6	$62.23	$71.4
Combustion Systems Emission Control (Clean Coal Tech. Fund)	15.0	0.0	0.00	2.0
Fossil Energy Subtotal	$73.6	$64.6	$62.23	$73.4
Conservation R&D				
Heat Pumps & Prime Movers	$ 5.0	$ 5.8	$ 6.600	$10.0
Industrial Cogeneration	5.0	5.0	4.600	0.0
ECUT (Gas-Related)	6.0	8.9	13.420	8.5
Indoor Air Quality	6.0	1.9	1.390	3.0
Desiccant Systems	0.0	0.7	1.265	8.0
Natural Gas Vehicles	0.2	0.0	0.000	9.5
Conservation Subtotal	$22.2	$22.3	$27.275	$39.0
Solar & Renewables R&D				
Biofuels (Gas-Related)	$12.1	$ 8.5	$ 6.5	$ 5.0
Geopressured Resources	4.0	5.0	6.0	8.4
Solar & Renewables Subtotal	$16.1	$13.5	$12.5	$13.4
Total—Fossil, Conservation, and Renewables	$111.9	$100.4	$102.01	$125.8

1/ Includes geoscience activities.

DISCUSSION

Mrs. LLOYD. David, that is excellent testimony. You are a very articulate spokesman for your industry and, obviously, the industry is doing a lot of good things and certainly putting lots of money into research and development.

You did make a good case for an increased focus on gas research with your recommendation for Assistant Secretary for Gas and Oil. Since this responsibility does fall under the Fossil Fuel Secretary, Fossil Energy Secretary, how would you envision coordination between these two offices?

Mr. WEBB. It seems to me they would do it two ways. One, they could either have an Assistant Secretary or, within the Fossil Energy Program——

Mrs. LLOYD. I guess my point is wouldn't this be a duplication of efforts?

Mr. WEBB. I don't think so. What we would propose is if you created Assistant Secretary for Oil and Gas, or Deputy Assistant Secretary, you put all of the oil and gas and geosciences-related research. That would be about $50 million a year if you took it from all of the different parts of DOE that have areas involved in that.

Let them also be the primary reservoir of information on resources in the country, applications, and then, when EPA or somebody is looking at putting out new regulations, or Congress wants somebody to testify what role could gas play actually in helping mitigate some of these environmental concerns, there would be a central spokesman for that.

We have had very good relations with the Fossil Energy Program. We don't really have a problem with the Fossil Energy Programs, but they are in the process of trying to implement this Clean Coal Technology Program. You're talking about funding in addition to $150–$300 million of basic coal research another $600–$700 million a year of R&D.

The oil and gas part of the program is just getting overwhelmed. And we think, if you look at the resource base in this country, we need to focus more attention on that.

Mrs. LLOYD. Basically, you're saying, since the fossil program concerns environmental matters that really are not related to the R&D that you are doing?

Mr. WEBB. Yes. And also the fact that with the Clean Coal Technology Program which Congress I think endorsed in '86 and '87, the Administration is now proposing to fund, I believe, on the accelerated basis. We are talking about $20 million out of about a one billion dollar program that is related to oil and gas.

And we think that if you look at the resource in this country and you look at how energy is used today, that is in disproportion. We need some way to focus attention from a policy standpoint on the role and contribution that gas can make.

Mrs. LLOYD. I was interested in looking at your Exhibit 1, the primary energy consumption for the year 2010, the outlook.

You did not—it reflects a decline in the use of natural gases. Is this your assumption based on the fact that we're not spending enough on research and development?

Mr. WEBB. That is part of it. The other part is that, as a percent of a larger total, the total amount of gas consumed in our projection was indicated to be about 19 trillion cubic feet per year.

Unless we get some major policy initiatives in the environmental area, it is business as usual.

Mrs. LLOYD. You have a larger pie for coal.

Would you like to comment on that? On this assumption?

Mr. WEBB. We are assuming by the year 2010 some of these technologies being developed under the Clean Coal Technology Program will, in fact, be commercialized and will be implemented and developed, you know, which addresses some of these environmental concerns.

Mrs. LLOYD. What really surprised me with the pie chart is that you haven't included a larger share of the pie for nuclear.

Mr. WEBB. All we have done on nuclear is taken the number of plants that have been announced, that are under construction, and put those into the program. And the coal program, essentially, it is the same way. If you look at the number of plants and stuff that have been projected in the future, it would appear to us, unless we solved some of the waste problems and developed, if you would, a more inherent reactor design that is safer, I don't see how you get a CEO of a major utility to commit his career to building a large plant that through the legal process in the way that we work the country today it takes 15 years to complete.

And he may end up with half of the cost being disallowed by the regulatory community as not used and useful. So, you end up with a CEO betting his career on a single plant.

And I think until that environment, particularly from an investment standpoint, changes, I don't see how you're going to get them built. I just don't think you are.

Now, that is not saying between now and then things wouldn't change in a policy nature and Congress wouldn't take steps that could reactivate that.

Also, some of the environmental concerns may cause people to take another look at nuclear energy. Our projections are assuming you haven't changed the laws that are in place today.

I cannot predict what changes are coming in the law. I am trying to keep it as much as I can related to just actual data that we have in our models.

Mrs. LLOYD. It is certainly the goal of this Committee not to promote one technology over another technology. But, to certainly maximize the use of each technology so that we will have options available to us that will reflect our needs as a nation.

Mr. WEBB. There is no single solution.

Mrs. LLOYD. That is correct. I was interested in your remarks related to the gas heat pump that this certainly is a near-term solution to our energy dilemma.

Do you feel that we are really maximizing the potential? When do you think we will have a gas heat pump on the market.

Mr. WEBB. I think, in the commercial sector, we will be field-testing in 1990 or 1991 a heat pump that, hopefully, would start to be manufactured by 1993. We're a lot more optimistic than we were a few years ago.

While there's still some technology problems that have to be solved primarily in getting the initial cost of the unit down, we have been able to achieve the performance targets that we set out.

In other words, you know, the coefficients of both heat included. Heat pumps are really unique in that not only can you heat and cool for less gas than you now use for heat alone, you tend to reduce the peak electric demand load in the summer which exaggerates the problems electric utilities have in trying to build enough capacity for peak demand and then having excess capacity during the rest of the year.

Also, the cooling market would be in the summer shorter months when natural gas use is down, so it would tend to stimulate, if you would, a more normal year-around demand from the standpoint of the producing community to develop the resources to produce our gas.

So from our perspective, the electric utilities might not agree that we have about 40 companies that are a combination of gas and electric utilities. We think it helps both the gas and the electric side at the equation.

Mrs. **Lloyd**. I agree with you. I am a TVA consumer. And of course we are stretched at some point in the summer to provide the capacity for the electric heat pumps. I have an electric heat pump so I was most interested in your remarks. It seems you are doing a tremendous amount to further technology transfer and certainly this is a major concern of this Committee.

And I want to commend you for your efforts in this area and hope that you will share with the Committee ways that we can enhance technology transfer to get more and more of our worthy products to the marketplace.

Mr. **Webb**. Thank you very much.

Mrs. **Lloyd**. Thank you very much.

Mr. Morrison.

Mr. **Morrison**. Thank you, Madam Chairman.

Mr. Webb, I look at GRI as maybe the best example we have of that industry-related mechanism which works cooperatively with the Department of Energy. And I just want to compliment you because I think your presentation, as well as the quality of the work you have done through the years, certainly sets an example for others. And it is very, very helpful to us. So we appreciate that.

I want to ask you a similar question as I put to the Department of Energy. Your statistics and your statement point out that we will still, by the year 2010, we will still get 58 percent of our energy from oil and gas, which is, I think, a little cause for concern as far as a number of us are involved.

And, yet, I think also in your statement you indicated that most of the sources of that oil and gas have not even been discovered yet, or they are requiring some heroic means to get those products out of the earth.

Are we making the kind of progress we have to in order to maintain that level of dependence?

And also at what price is that 60 percent of our energy supply going to come?

Mr. **Webb**. Mr. Morrison, in response to the first part of the question, no, I don't think today that we are seeing either the commitment from the federal government or from the producing infrastructure that is going to be required to develop these resources.

We are going to have to develop advanced technology, not only to extract them but to keep them cost-competitive, because one-third of gas usage is in areas where other fuels can also perform the function. Maybe not quite as well, but they can perform the function so that you're cost- competitive, if you would, with oil and, in many cases, coal.

So, the price that—I am using the DOE study. They finished this study last May where they assembled together a group of people and assessed in 1988 dollars, they estimated you could recover about 600 trillion cubic feet at $3 in 1988 dollars.

So, depending on different assumptions about inflation and what have you, in the year 2010, that certainly is not $3 in real dollars. But, in 1988 dollars, $3 per thousand cubic feet.

Now, that compares to today probably producers are getting about $1.50 at the wellhead. So, essentially, about doubling the price at the wellhead. They estimated that, with advanced technologies, you could get an additional 600 trillion cubic feet.

But, the first part of your statement is correct. The oil and gas that will be consumed in this country in the year 2010 is in fields that have not yet been developed. It is not going to come from our existing fields and reservoirs because the life of a field varies anywhere from seven to 15 years, and we are talking about 20 years from now.

Mr. MORRISON. In the natural gas area, are you relatively confident it is out there? I am worried about the petroleum area because we are just not having those new finds; we are not drilling the wells.

What is happening in natural gas?

Mr. WEBB. In natural gas, we think it is out there. Two things have happened over the last few years that has changed some of this thinking. One, we have always known in this country that we only recovered about one-third of the oil. And that is the reason there is such a big push for enhanced oil recovery, because you leave two-thirds of it in the reservoir.

We had assumed, based on the few giant fields of gas we discovered back in the early forties, that you recover 85–90 percent of the gas because it is a homogenous reservoir. It's got large sand pores and the gas flows out.

We are now discovering that in fact is not the case. In many of the reservoirs, we would only be recovering 50–55 percent. I think the field in Kansas and some of the work now going on in West Texas is proving that in that they are drilling offset wells and getting pressures as high as the initial wells discovered in the field, and production rates as high.

So a lot of the research we are focusing on is better instrumentation and diagnostics that would allow us to figure out what would be the optimum well spacing for drilling in a field.

We think there's quite a bit of gas that's going to come through that. We know there is a lot of gas in tight formations. It is not a matter of finding it; it is a matter of producing it at a price that is competitive.

There's a lot of gas in the tight sands formation that is run out under the Rocky Mountain area. There is a lot of gas in the methane in coal bed seams that are running all up and down Appalachia.

We had a major program in methane from coal seams with producers and there are now several companies, that's all they do.

And we are seeing something on the order of a thousand wells a year drilled to extract gas, if you would, methane from coal seams. While you don't get nearly as much gas per well as you would in a sand reservoir, the life of it is 20–30 years and it is 2,000 feet in depth, and you don't have to have real sophisticated completion techniques.

So we are—I say "we"—we get a royalty on some of these, and they are selling it at $1.50 and they are making money on it. They're paying us royalties and they are selling it. So I have got to believe they are making money.

There are a lot of things that can be done in those areas, we just need to mount a comprehensive R&D program. We are willing to be partners with government, but we need really stability I think as much as anything. So that if one year we start a program, the next year we know funding will be there to continue it.

Our biggest problem is Congress has been very good at trying to maintain a level program in these areas, you know, continuing the program. But, when the Administration due the budget restraints reduces the budget by 50 percent or 60 percent, then our industrial partners are also putting up money and they get very nervous about entering into these joint ventures, if you will.

So I wish we could figure out some way to convince the Administration that some of these areas, it would be cost- effective if they would mount a program and stick to whatever we agreed to over a five-year program, and let us put up half the money with our industrial partners and do the research.

Mr. **Morrison**. Do you have some good examples of some programs that have had a federal investment, cooperative investment and are ready to go to marketplace, and are removed from any necessary federal funding?

Mr. **Webb**. Yes. The one I would use that I think is probably typical of many is the fuel cell program. We started in 1982 in a joint program with industry and with DOE to develop a phosphoric acid fuel cell system.

The program now is to the point that the manufacturer is trying to develop the very first units to be put into commercial production. But the DOE policy is, once it gets past a certain phase, they will not invest any more money in it.

So, what has happened is we have spent—we, GRI and the federal government cooperatively—probably spent about $120–$130 million and the manufacturer probably spent $50 million bringing the technology where he is now ready to set up a production line, and get firm commitments to build the prototype.

The manufacturer still has to find another $60 million to make this initial commercial investment. It seemed to me that the federal government, which uses a lot of energy, ought to be, instead of a procurer of last resort, of first resort. They ought to make some of these initial orders to help guarantee the manufacturer that there's going to be some product—excuse me—a market for these initial units to help us, first, to get them into the marketplace and get them accepted as a viable alternative, and second, help him to start coming down the cost curve as he develops his manufacturing process.

They don't do that now. I think that would be a very good policy for DOE, or any parts of the federal government. The emerging technologies, if they would purchase some of the initial units—not all of them, but some of them along with industry—to help, if you would, with the market pull, I think it would be a very cost-effective step to be made.

They didn't do that in fuel cells, so the manufacturer on his own now is trying to get enough firm orders that he can justify to his boss: Give me $60 million to set up a production line in this very risky venture that, hopefully, some day I will be able to pay us back, you know, the corporation.

Mr. MORRISON. That is an interesting approach. Thank you very much.

Mr. WEBB. You're welcome. Thank you.

Mrs. LLOYD. Thank you, Mr. Morrison.

Mr. Fawell.

Mr. FAWELL. I have no questions.

Mrs. LLOYD. Mr. Smith.

Mr. SMITH. Thank you, Madam Chairman, and let me also thank you for inviting someone from the oil and gas industry to appear before the Subcommittee today.

Mr. Webb, I appreciate what you had to say and certainly agree with everything I heard. Let me point out a couple of points that you made in your prepared statement.

The first is that you talk about the need to develop the United States extensive domestic gas resources to reduce our dependence on foreign oil.

I couldn't agree more. And, of course, today, we import 42–43 percent of our fuel.

My question to you, and I hope you and I would agree on the answer, is:

So what? What difference does it make that we are importing 42 or 43 percent of our fuel? And if it makes a great deal of difference, have we, in fact, reached a crisis point in America today?

Mr. WEBB. The first part of the question is I think as a national policy to allow us to get so dependent on imported oil that, number one, we are destroying the producing infrastructure to develop our own domestic resources is a mistake.

Secondly, as we probably won't be as lucky the next eight years as we were the past eight years in not having some kind of an interruption or some kind of an event that would cause us, all of a sudden, to either be deprived of some of our imported resources, or the price of it get to be so expensive that we are beginning to find that we are beginning to enter into an economic downturn.

So I cannot tell you what the magic number is. Obviously, being totally independent is not good policy either because the lowest cost producers of oil happen to be in the Mid-East. That is just a geographic phenomenon; there is not anything we can do about that.

But the cheapest source of energy in this country is conservation; from the standpoint of the amount of energy we use in this country, it is possible to develop technologies to use it more effectively.

And, secondly, it is in the U.S., at least I think there are a whole lot of gas-prone provinces that haven't really been developed, because gas up until 15 years ago was not an integral part of our energy mix.

And in the early years, gas was produced as a by-product. So you had a lot of gas that was discovered in association with oil, but we didn't develop the technology nor the applications to look at gas-prone province. I think there's a lot of domestic gas out there.

The impact on our balance of payments gets to be—if we end up importing 10 million barrels a day, which means probably if we get up to the level OPEC has gained enough control of the market that they can extract something above inflation in the way of economic rent for developing their resources, I just don't see how we solve our import—our balance of payments problems.

I think all of this is inter-related.

Mr. SMITH. I agree with you. Let me simply add to what you said. In my judgment, if we lose our energy independence, we also jeopardize our national security. And that is something that concerns me as much as anything else.

Another point you made in your statement, which has already been referred to by the Chairman and Ranking Member of the Subcommittee, is the fact that '87 consumption in the United States other energy relied on gas and oil to meet 63 percent of our demand.

The projection is that by the year 2010, the United States will still get 58 percent of its energy from oil and gas.

I would simply say here that I don't know of the statistics that I have seen that it's more persuasive or more informative or should influence Members of Congress more than that particular statistic as far as the balance we need to achieve in the energy budget goals. We simply need to devote more federal dollars to the research and development, the exploration and development of our natural gas fields in America.

Thank you, Madam Chairman.

Mrs. LLOYD. Thank you very much, Mr. Smith.

Dave, if you ever get tired of your job, Congresman Smith will help you [laughter], make some of your appointments.

He is also is an excellent spokesman for your industry.

Mr. Wolpe.

Mr. WOLPE. I have no questions.

Mrs. LLOYD. We're awful happy to have Mr. Wolpe back on the Subcommittee. He has been absent for a period because he served on the Budget Committee. We have back one of our former Members.

Thank you very much, Mr. Webb, for being with us today.

Mr. WEBB. Thank you, Madam Chairman. I appreciate it.

[Witness excused.]

Mrs. LLOYD. Next, we will receive testimony from Mr. Marc Ledbetter who represents the American Council for an Energy Efficient Economy; and Dr. William Kirsch from the University Science Center.

Gentlemen, we have your testimony and you may proceed as you wish.

PANEL 1

STATEMENT OF MARC LEDBETTER, SENIOR ASSOCIATE, AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY

Mr. **LEDBETTER**. There was an error in the graph that was in the pre-filed testimony, so if you want to work from this testimony, you'll see the correct labeling—that's right.

Mrs. **LLOYD**. If you would supply a copy to our reporter.

[Handing document to reporter.]

Mrs. **LLOYD**. Mr. Ledbetter, please proceed.

Mr. **LEDBETTER**. Thank you, Madam Chairman. You alluded earlier to the problem of global warming and the majority of my testimony focuses on global warming and how energy efficiency addresses that problem.

As I am sure is no new news to this Committee, human activities in the area of energy consumption and the release of other greenhouse gases are now taking place on such a scale that we have threatened the climate of this planet, threatened it seriously. And I am sure you have heard some of the dire predictions of what could happen if we continue on our present trends.

The best climate models that are available to us now project that if we stay on current trends that future average temperatures around the globe will rise between 2 and 9 degrees F. by the middle of the next century. And the scientific community has now come largely to the conclusion that we understand the problem well enough to take some remedial actions.

Certainly, there are a lot of uncertainties left in the problem in predicting the severity of the consequences of global warming where these things might occur around the globe. But there is a fairly strong consensus now in the community that we understand the problem well enough to take remedial action.

As a matter of fact, that opinion was expressed recently in a message sent to the President by the National Academy of Sciences. And in that message, they said that:

"We are already irrevocably committed to major global changes in the years ahead."

And I am quoting now from that statement.

"The elevated concentration of greenhouse gases produced today by human activities will persist for many centuries and will slowly change the climate of the earth regardless of our actions." Quote.

They went on to state that:

"Prudent actions should be initiated or intensified to improve our abilities to predict these changes and their economic and social consequences and to develop suitable policy responses." Quote.

So the National Academy of Sciences is saying:

It is time to act.

Now, the scale of this problem is so large that it is going to be necessary that we adopt a very broad set of policy responses. There is no single technological fix that we're going to be able to pull out of the bag, or no single policy response that we're going to be able to rely on.

It is going to take a very broad response. But, among all of these responses that are going to be necessary, there is without question one policy response that stands above all others in importance. And that is energy efficiency.

And that is at least within the next 30 or 40 years, what we can define as the near-term in this global warming problem, there is no other technological option that is going to reduce future carbon emissions more than an effort to improve our energy efficiency.

Now, if you could please refer to figure 1 in my testimony, and this was the figure that had some lines mislabeled, the Committee has the correct version and I apologize to you in the back of the room who may have picked up copies of it with the incorrect version. But the correct versions are on the table, and I want to refer you to this graph because it illustrates the point that I am making.

The graph was produced by some model runs from a model called the Edmonds-Reilly model that is used very widely in the scientific community to analyze the effects of various policy actions on addressing future carbon emissions.

It is a general equilibrium model of the World Energy System and plotted on this graph are two scenarios. The top line shows future carbon emissions if we improve our energy efficiency at the rate of about 1 percent per year. And by improving our energy efficiency at the rate of 1 percent per year, I mean improving or decreasing the energy used per unit of world economic output by the rate of 1 percent per year.

In the lower line, efficiency improvement, is 2 percent per year. And as you can see, when you get out to the year 2030, the difference between the two scenarios is—well, the scenario with the 2 percent efficiency improvement is half—has half the carbon emissions as the other scenario.

So, clearly, this is going to have an enormous effect on future carbon emissions if we just make that much of an adjustment in the rate of efficiency improvement.

Now, improving efficiency at the rate of 2 percent per year is going to be no small task. There were countries in the world in the 1970s that improved efficiency at a rate that is greater than this. But, of course, we had soaring energy prices to spur that along. And we had a lot of government focus on the energy problems. And there are only some countries that did that, primarily, the industrialized countries.

Most of the developing countries went ahead and saw their energy use continue to rise during that period. So, in order to have the whole world improve efficiency at that rate, it's going to take a monumental effort.

A second graph I want you to take a look at that further illustrates the point I am making of the importance of energy efficiency, is in figure 3, attached to the back of your testimony. It is a bar chart.

This bar chart is taken from a study that is being done at Oak Ridge National Laboratory. The study is looking at all of the options that we have available to us for addressing global warming.

You can see the bar on the far left shows the total carbon emissions in the U.S. in the year 1987. And it amounts to 1.36 billion tons of carbon emitted in 1987.

And then projecting out into the future to the year 2020, if we continue with the same energy mix that we presently have, you can see that carbon emissions will soar to around a little over 2 billion tons of carbon per year.

This is the second bar from the left on the graph.

And then, if you look at the two top segments of that bar, they show the reductions that you can get from an aggressive research and implementation program with non-fossil sources and the two major contributors there, as you can see on the graph, are liquids from biomass and reductions due to nuclear electricity. That can get you a substantial reduction in future carbon emissions.

But, if you look at the third bar from the left, that bar shows you what you can get from combining a major efficiency effort with efforts to develop non-fossil resources. You can see that the carbon emissions plummet and amount to no more than a little over .5 billion tons of carbon.

So, clearly, the single largest contributor to reduce future carbon emissions as projected in this study being done by the Oak Ridge National Laboratory is an effort to improve energy efficiency.

Now, not only will energy efficiency have the largest impact among the options for reducing carbon emissions, it has the unique advantage of paying for itself.

It is almost a no risk policy. There is of course risk involved in everything. But, among all of the options that we have available, it is very attractive in that the savings from implementing these programs pay for themselves, will generate enormous economic benefits in trade deficits, in balance of payments, and on and on.

It is just a major economic boost for our economy to go in this direction. So, even if you were to believe some of the nay-sayers that say "Global warming is still a theory and that we need far more research before we can act on it," if you were to buy into that line of thinking, we could still justify a major effort to improve energy efficiency.

Now, one of the most important components to improve energy efficiency, or policy components, is in the area of research and development, which is of course the business of this Subcommittee.

We have had a lot of success with research and development, both in the private and government areas since our energy problems developed in the early 1970s.

We have saved a tremendous amount of energy in the United States. Efficiency has improved by a very large amount. We estimate the U.S. is saving somewhere on the order of $150 billion per year now as a consequence of efficiency improvement since 1973. And a large part of that efficiency improvement was based on research and development, just the knowledge of how to improve our efficiency.

A recent evaluation of the federal programs, the federal energy efficiency programs, concluded that just seven technologies that were advanced by federal involvement will save this economy on the order of $50 billion; whereas, the federal cost for developing those technologies was only $17 million.

It is an enormous payback for a very small federal contribution. Nonetheless, we have seen these programs sharply cut back. Efficiency funding now stands at about one-third of its 1980 level. That is an inflation-adjusted number.

I would urge this Subcommittee to take a leadership role in the area of conservation R&D and reverse the trend that we have seen for year after year, and increase funding for conservation R&D.

If we are to take the global warming problem seriously, we are talking about a substantial increase in conservation R&D funding. We support the numbers that are in the Claudine Schneider bill. I believe the bill was just introduced about a week ago, it's called "The Global Warming Prevention Act of 1989."

Short of those substantial funding increases, we recommend that this Committee take a serious look at some ideas that we have generated. I have attached a list of these ideas to the back of my testimony. There are about 40 new research projects that we think deserve funding. And since time does not allow, I will just select a couple of those to give you an idea of some of the very worthwhile research that is not being funded right now.

The first research project I would like to highlight is a research project that would support the development of energy performance labels for windows. We have seen a tremendous improvement in windows in the last six or seven years. A large part of this improvement is due to federal involvement in developing the technology.

There is window technology that is called low emissivity glass selling like gangbusters. We have the federal government to thank for that because the window industry was very reluctant to bring that technology to market. And with a little bit of boost from the federal involvement, we saw the technology brought on in 1983.

What I have here is an example of a further refinement of that technology. This is a piece of glass that, at the center, has a thermal resistance of about R-8. When this window is modeled in a building in a northern climate, say, like Madison, Wisconsin, it outperforms a wall that would be insulated to a value of R-100.

The reason is because, first, it has a strong resistance to thermal heat flow out of the building, but also it can collect diffuse solar energy from the outside. This out-performs a very well-insulated wall in a northern climate.

I show you this because I just want to highlight that there have been a lot of changes going on in window technology, and we're going to see a lot more coming. But the people that are responsible for buying these windows, the architects, the engineers that specify windows, and even the smaller builders do not have reliable information for buying these windows.

They don't have a good basis for comparing the energy performance of various windows.

So we recommend a national window labeling program similar in nature to, say, the MPG labels that are put on automobiles. The labels are put on appliances. That would give people who buy these windows some good, reliable information to make their comparisons.

We just can't come up with those labels immediately. It is a very complicated project to do that. Research is needed to support the development of these labels. We have to standardize testing procedures and develop state of the art simulation models that will enable us to develop the performance values that can be assigned to these kinds of windows.

The second project I would like to highlight is in the area of urban heat islands. It may be a term that you have never heard before, but I predict that we're going to be hearing more of it in the next few years.

Larger urban areas in the United States have outdoor temperatures during the summer about 5–10 degrees warmer than the surrounding countryside. These higher temperatures are largely due to the poor reflectants of a lot of building materials and pavement materials that are used in the cities and very little tree cover.

These pavements and buildings are not very well-shaded. I have seen plots of the City of Los Angeles showing how the temperature has risen substantially since the 1930s, when many of the orchards were removed from the Basin.

So we have an uncomfortable climate that we are creating in these Cities. But, important from the energy point of view is that these higher urban temperatures exacerbate the electric loads that are put on our air conditioners. They make them much larger.

Early calculations of what we could save by increasing the reflectivity of building materials in these areas and by increasing tree covers in these areas show that we could save on the order of 30 percent of our cooling energy.

Now, that is a very preliminary number, but it points out that we may have an enormous opportunity here to save cooling energy. And, by the way, the cost of reducing that electrical consumption works out to around 1 penny per kilowatt hour, which is far less than the cost of supplying new energy from new sources.

We would urge that this kind of program receive funding because, obviously, it could pay enormous dividends in the savings of billions of dollars and in reduced carbon dioxide emissions.

I think I will stop there. If the Committee would like any additional information on any of the other items that are on the long list that I attached to the back of the testimony, I would be happy to provide it.

[The prepared statement of Mr. Ledbetter follows:]

TESTIMONY OF MARC LEDBETTER
REPRESENTING
AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY
ON
ENERGY CONSERVATION R&D
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
HOUSE COMMITTEE ON SCIENECE, SPACE AND TECHNOLOGY
February 28, 1989

Deforestation, release of CFCs, and combustion of fossil fuels now take place on such an enormous scale that the earth's climate is seriously threatened. Based on the current understanding of the effect of greenhouse gases on the environment, atmospheric scientists expect that before the middle of the next century, global mean temperatures will rise between 2 and 9 degrees fahrenheit. Rising temperatures are projected to change patterns of rainfall, cause northward retreat of U.S. forests, increase sea levels, erode beaches, and wreak havoc on agriculture.

Although much more research will be necessary to validate and refine the theories and models that predict unprecedented climatic change, our understanding of the problem and the threat it presents are sufficient to justify remedial action.

In the words of the National Academy of Sciences in their recent recommendations to President Bush:

> We are already irrevocably committed to major global change in the years ahead. The elevated concentrations of greenhouse gases produced to date by human activities will persist for many centuries and will slowly change the climate of the earth, regardless

> of our actions....Prudent actions should be initiated or intensified to improve our abilities to predict these changes and their economic and social consequences and to develop suitable policy responses.

Of all human activities that are causing changes in the earth's atmosphere, none is more important than fossil fuel combustion and its resulting emissions of carbon dioxide. Energy use is the principal factor driving climate change today.

Among the four specific, near-term actions recommended by the National Academy of Sciences to President Bush was the following:

> Policies should be formulated and implemented to foster energy efficiency and conservation, to increase use of natural gas rather than other fossil fuels, and to enhance research on and use of non-fossil fuel energy sources, including "safe" nuclear and solar alternatives.

The enormity of the global warming problem and the threat it represents to human welfare make it necessary that the United States and other countries adopt a broad set of policies to address global warming. No single policy or new technology will be sufficient to reduce emissions of greenhouse gasses enough to remove the catastrophic threat posed by global warming. But without question, there is one policy response that, for at least the next thirty or forty years, stands above all others in importance. That policy response is an international effort to improve the efficiency with which we use energy. Over the next emissions.

An ongoing study by the Oak Ridge National Laboratory further illustrates the importance of improving energy efficiency.[2] In this study William Fulkerson, et al have estimated the potential for reducing future CO_2 emissions in the United States through aggressive R&D and use of new technologies. They estimate that annual carbon emissions, which totaled 1.36 gigatons in 1987, would only grow to 1.6 gigatons in the year 2020 if we were to aggressively research and develop non-fossil sources of energy, primarily nuclear and liquids from biomass. On the other hand, if we also aggressively researched and used energy efficiency technologies, we have the potential to reduce carbon emissions in the year 2020 to .53 gigatons per year. (See Figures 2 and 3.) In short, their research shows that by the year 2020, aggressive energy efficiency research and implementation can reduce carbon emissions by more than twice as much as aggressive research and implementation of non-fossil sources of energy. Fulkerson and his colleagues state, "Increasing energy efficiency would likely be the least costly, most effective, and quickest strategy for reducing CO_2 emissions initially."

Not only will energy efficiency improvements have the largest impact among the options for reducing future carbon emissions, it has the unique advantage of paying for itself. Its economic benefits in the form of a reduced trade deficit, more institutions. A surge of technology improvements in energy consuming devices and building materials, as well as our much improved understanding of the physical and societal factors that affect energy use, has made it possible to hold energy use between 1973 and 1987 almost level while the economy grew by about 40%.[3] Research and development has yielded the knowledge upon which this improvement in energy efficiency is based.

The federal government was a very important participant in this research. Its programs have yielded a large number of highly valuable products and technologies. A recent evaluation of technologies advanced by the federal conservation research and development program estimates that just seven of these technologies will save the U.S. economy over $50 billion.[4] The federal investment in these technologies was only $17 million. Despite these successes, the federal conservation R&D program has been sharply cut back. On an inflation-adjusted basis, the program now receives only about 1/3 its 1980 level of funding.

Given the track record of this program, its potential to help this nation, and the enormous threat represented by global warming, funding for this program must be increased. Among the steps the federal government could take to speed the improvement of energy efficiency in the United States, increased R&D spending is among the most important, and among the most politically possible. This subcommittee should take a leadership role in addressing global warming. It can begin that role by may over- or under-state the capabilities of the new window technology. Inconsistent and confusing product data on new windows slows sales of improved windows and reduces energy savings for the homeowners and for the nation. Specifiers and purchasers of windows need a simple and accurate way to compare window properties and performance. We propose that a national window labeling program provide this information.

The choice is not whether there should be labels for windows. Dozens of different labels used to identify window performance exist today. However, there is no consistency among these labels; numerous procedures are used for calculating window properties. We need a national, uniform, accurate labeling system, similar in nature to the mpg labels found on cars and the energy consumption labels found on refrigerators.

A window label should include information on physical properties (e.g. U value, shading coefficient, etc.) and energy performance. The process by which such a label is developed might be complex and use state-of-the-art simulation tools, but the resulting label could still be simple and easy to use. Before such a labeling system can be developed, research is needed to develop an accurate and useful label, as well as the calculation procedure to support it.

We believe that the Department of Energy is the most appropriate entity to conduct this research and urge that funds dollars of avoided investment in electric peak generating capacity and in avoided emission of CO_2.

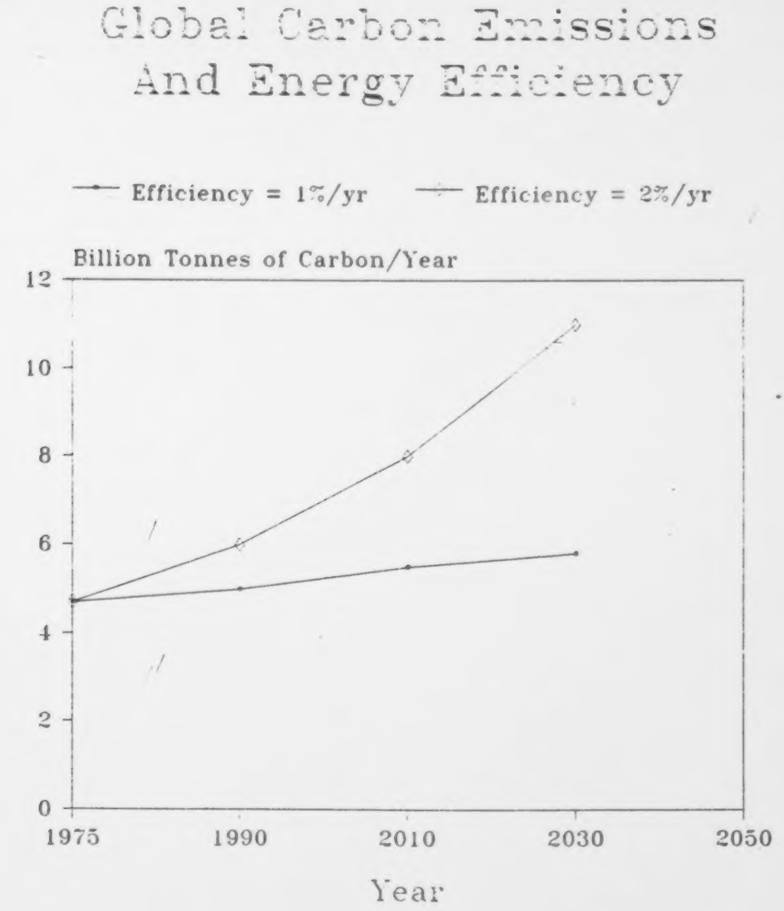
Land development processes are fragmented, and there is thus little incentive to invest in the development of techniques for new urban designs that reduce energy consumption. Cities and states have not take the initiative. The research needed is beyond the technical resources of cities. Implementation of the expected research implications requires crosscutting, multi-sector coordination. To realize the savings potential, a DOE initiative is appropriate, with cost sharing by utilities, state, and local governments and industry.

Preliminary calculations indicate:

- More than $20 billion savings of avoided cost for electric generating capacity and building HVAC equipment
- More than $4 billion of energy savings per year
- About 18 million tons per year reduction in CO_2 emissions from power plants, plus additional capture of CO_2 in trees

The research initiative would be a five year effort, and would involve data gathering, modeling, verification of energy savings, and development and dissemination of implementation guidelines. We recommend funding of $1 million in FY 1991, $1.85

Figure 1



Global Carbon Emissions And Energy Efficiency

Energy Efficiency: A Tool for Slowing Climatic Change

Figure 2

Potential reduction in U.S. CO_2 emissions via efficiency improvement and/or nonfossil energy sources assuming energy technology R&D successes

	1987	2020				2040				
	Actual	Base case[a]		High efficiency[b]		Base case[a]		High efficiency[b]		
		A[c]	B[d]	A[c]	B[d]	A[c]	B[d]	A[c]	B[d]	B'[e]
ELECTRICITY GENERATION, 10^9 kWh(e)										
Oil	119	500	500	120	220	800	400	120	0	0
Gas	273	800	800	450	450	1200	800	480	0	0
Coal	1464	3521	2421	1200	0	4627	1097	2272	0	0
Subtotal	1855	4821	3721	1770	670	6627	2297	2872	0	0
Nuclear	455	500	1500	300	1500	170	4000	170	2710	4000
Hydro	250	475	475	475	475	475	475	475	475	475
Solar, etc.	12	25	125	225	125	25	525	25	357	525
Subtotal	717	1000	2100	1000	2100	670	5000	670	3542	5000
TOTAL	2572	5821	5821	2770	2770	7297	7297	3542	3542	5000
PRIMARY ENERGY USE, quads										
Oil—Electric	1.26	4.9	4.9	1.2	2.2	7.8	3.9	1.2	0	0
Non-electric	31.38	31.6	21.6	14.8	10.7	31.3	21.3	21.8	14.0	7.3
Total	32.64	36.5	26.5	16.0	12.8	39.1	25.2	23.0	14.0	7.3
Gas—Electric	2.94	7.8	7.8	4.4	4.4	11.7	7.8	4.7	0	0
Non-electric	14.23	13.0	13.0	12.6	8.6	13.5	13.5	16.2	14.0	10.0
Total	17.17	20.8	20.8	17.0	13.0	25.2	21.3	20.9	14.0	10.0
Coal—Electric	15.19	34.3	23.6	11.7	0	45.1	10.7	22.2	0	0
Non-electric	2.83	6.9	6.9	4.9	3.0	12.2	12.2	3.0	3.0	3.0
Total	18.02	41.2	30.5	16.6	3.0	57.3	22.9	25.2	3.0	3.0
Total fossil	67.83	98.4	77.7	49.6	28.8	121.6	69.4	69.0	31.0	20.3
Biomass (non-electric)	0	0	20.0	0	20.0	0	20.0	0	20.0	20.0
Nuclear	4.92	5.3	16.0	5.3	16.0	1.8	42.7	1.8	28.9	42.7
Hydro	3.01	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Solar, wind, geothermal	0.25	0.2	1.2	0.2	1.2	0.2	5.1	0.2	3.5	5.1
Total Non-fossil	8.18	10.2	41.9	10.2	41.9	6.7	72.4	6.7	57.0	72.4
TOTAL PRIMARY ENERGY	76.01	108.6	119.6	59.8	70.7	128.3	141.8	75.7	88.0	92.7
CO_2 EMISSIONS,[f] GtC/year										
Oil	0.63	0.73	0.53	0.32	0.26	0.78	0.50	0.46	0.28	0.15
Gas	0.26	0.31	0.31	0.26	0.20	0.38	0.32	0.31	0.21	0.15
Coal	0.45	1.03	0.76	0.41	0.08	1.43	0.57	0.63	0.08	0.08
TOTAL	1.36	2.07	1.60	0.99	0.53	2.59	1.40	1.40	0.57	0.37
TOTAL CO_2 FROM ELECTRICITY GENERATION, GtC/year	0.45	1.07	0.80	0.38	0.11	1.46	0.46	0.65	0	0

[a] "Base case" refers to Edmonds/Reilly model (energy, economy) base case, as discussed in Chap. 2.

[b] "High efficiency" refers to a high-efficiency scenario based on R. H. Williams, "A Low-Energy Future for the United States" (Chap. 2, References).

[c] Cases in "A" have limited contributions from nonfossil sources (e.g., no new nuclear reactors are ordered).

[d] Cases in "B" have the same fuel and electricity requirements as those in "A" but with assumed larger contributions from nonfossil sources, as described in Appendix C.

[e] "B'" involves additional electrification in the residential, commercial, and transportation sectors to exploit fully the assumed potential contribution of nonfossil sources of electricity.

[f] Coefficients used in calculating CO_2 emissions: 0.030 GtC/quad for oil, 0.015 for gas, 0.025 for coal (see text). (1 GtC = 1 × 10^{15} grams of carbon contained in CO_2.)

SOURCE: See endnote 2.

Figure 3

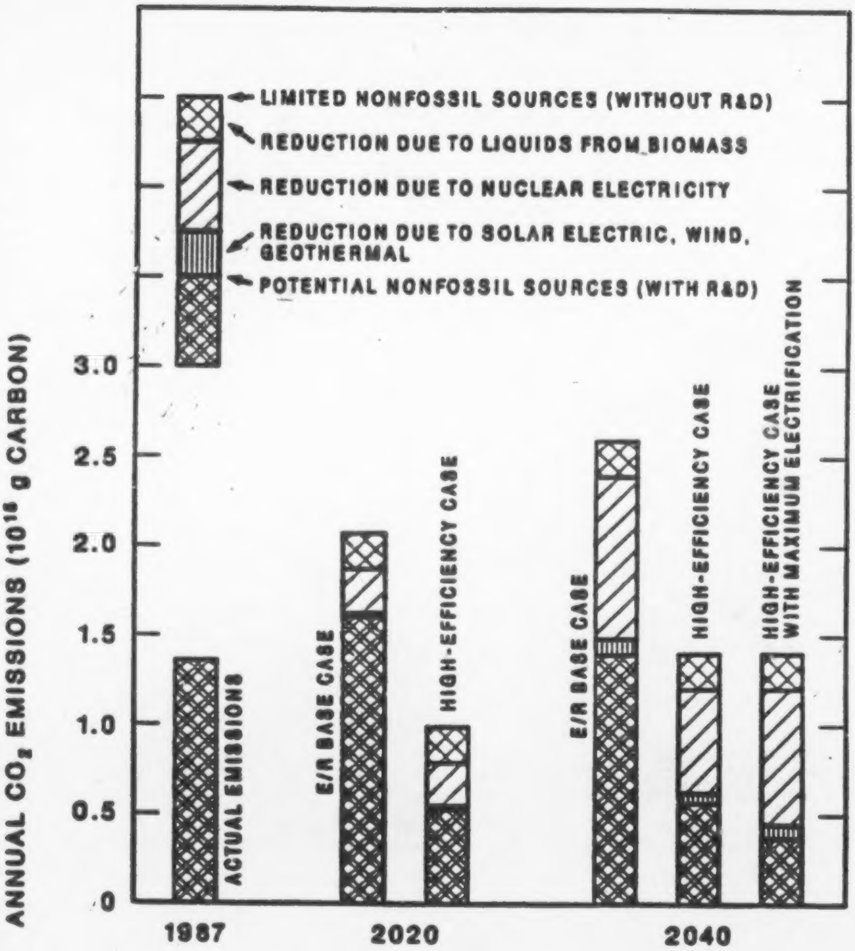


Fig. 4.3. Estimated potential of efficiency increases and nonfossil energy sources for reducing U.S. CO_2 emissions from fossil fuel combustion.

SOURCE: See endnote 2.

Suggested Increases for FY 1990 Conservation R&D Appropriations
(Not listed in order of priority)

	Proposed	Vs. FY 89
High Frequency Power Supplies for Advanced Light Sources (BCS)	.50	.50
Urban Heat Islands Reduction (BCS)	1.00	1.00
CFC Alternatives for Air Conditioning and Refrigeration Processes (BCS)	1.20	1.20
CFC Alternatives for Insulation (BCS)	.75	.75
Advanced Desiccant Systems (BCS)	.60	.60
Advanced Tools for Design, Construction, and Operation of Commercial Buildings (Intelligent Commercial Buildings) (BCS)	1.30	1.30
Research Support for Low-Income Weatherization and Federally Assisted Public Housing (BCS)	1.60	1.60
Critical Factors for Healthy Buildings (BCS)	.90	.90
Energy Labels for Window Units (BCS)	.50	.50
DOE\Utility\Industry\NAHB Consortium for Superwindow Develop. (BCS)	.60	.60
CFC Reduction Alternatives for Automobile Air Conditioning (TP)	2.00	2.00
Indoor Air Quality, Infiltration and Ventilation (BCS)	1.90	.50
Performance Simulation (BCS)	1.50	.75
Textile Industry Initiative (IP)	1.20	1.20
Production Microwave Sintering of Ceramics (TP)	.80	.80
Ceramics in Stationary Gas Turbines (IP)	.30	.30
Combustion Research Initiative (IP)	2.35	2.35
Ceramic Fiber Composite Initiative (IP)	.25	.25
Pulp and Paper Industry Processes (IP)	3.01	3.01
Waste Materials to Chemicals (IP).	.50	.50
Advanced Fuel Cells for Transportation Applications (TP)	1.50	1.50
Advanced Hybrid Vehicle for Transportation (TP)	3.30	3.30
Adiabatic Diesel, Railroad and Marine Applications (TP)	.40	.40
Waste Incineration Technology (IP)	.90	.90
High Temperature Superconductor Technology (ECUT)	2.00	2.00
Magnetic/Chemical Energy Conversion Technology (ECUT)	.80	.80
Surface Engineering Technology (ECUT)	.80	.80
Carbon Dioxide Fixation and the Greenhouse Effect (ECUT)	.80	.80
Building Foundation Research Network (BCS)	1.00	1.00
Sensors and Controls (IP)	13.00	13.00
Improving the Energy Efficiency of Federal Buildings (BCS)	2.00	2.00
Advanced Low-Emission Diesels for Automobiles (TP)	5.00	5.00
Energy-Efficient Technologies for Developing Nations (ECUT)	1.20	1.20
Supplemental Support for the Roofing Research Center (BCS)	.50	.50
Efficiency/Global Warming Study (ECUT)	1.00	1.00
Demonstration of New Federal Building Standards (BCS)	1.50	1.50
FEMP Demonstration of New Technologies (BCS)	2.00	2.00
Industrialized Housing (BCS)	1.50	1.50
Hot/Humid Climates Building Research (BCS)	.70	.70
Advanced Lighting Technology Transfer Initiative (BCS)	.20	.20
Thermally Activated Heat Pumps (BCS)	6.70	.50
Advanced Refrigeration Systems (BCS)	2.60	1.00

Mrs. **Lloyd.** Thank you very much, Marc. I am taken by your urban heat island reduction initiative. I would like to have more information, as well as the window labeling.

Mr. **Ledbetter.** All right.

Mrs. **Lloyd.** Dr. Kirsch, please proceed with your testimony.

STATEMENT OF DR. F. WILLIAM KIRSH, VICE PRESIDENT, INDUSTRIAL TECHNOLOGY AND ENERGY MANAGEMENT UNIVERSITY SCIENCE CENTER

Dr. **Kirsch.** I would like to thank the Chair and the Members of the Subcommittee for this opportunity to speak on behalf of energy conservation, in general, and energy conservation among small and medium-sized manufacturers in particular.

I am William Kirsch, the Director of the Energy Analysis and Diagnostic Center Program, or the EADC Program as it has become known. It is an industrial energy conservation program currently supported by the Department of Energy at a projected level of about $1.73 million per year.

This program has identified to date over $400 million in cost-savings and more than 82 trillion Btu in energy conservation for small and medium-sized manufacturers since its inception 12 years ago.

We know that from one year to another that half to three-quarters of the recommendations are in fact implemented because we gather these data one by one from each manufacturer.

What I am asking is for the Congress to continue support at a level of approximately $1.8 million per year of this program, which really has been generating far more dollars for the federal government than it has cost.

However, without continued federal support, the kind of support that is really seed money, the EADCs cannot survive. The program has two chief goals. The first is to help small and medium-sized manufacturers to become more competitive and remain more competitive by reducing energy costs through improved manufacturing operations.

The second is to offer engineering graduates and under- graduate students opportunities to gain practical industrial experience as part of their education.

To fulfill these goals, the university engineering faculty and students perform on site analyses of plants manufacturing operations and their energy use.

They make very specific recommendations to improve their clients efficiency and competitiveness, and they present these results through individualized reports.

My staff and I review not only all of these reports and provide feedback, we also go out and interview a large share of the manufacturers that have been served.

For example, during 1988, we interviewed 243 of them and we found a great deal of acceptance of the EADC program.

When we asked them:

"Do you think this is a good expenditure of taxpayers' money?" the answer was 94 percent yes. And that is a very real number. Over the years, it has remained between 90–98.

When we asked whether the energy audit reports are considered extremely well-done, or how well-done, and so on, the ranking "extremely well-done" is 93 percent.

When we ask them if they are going to implement some energy-conserving and cost-savings recommendations within two years, the answer again is 94 percent yes.

We also find out later specifically exactly how much of the manufacturers' conserving and cost-saving potential is, in fact, implemented; we also know the dollar value of their savings and we can estimate its value to the federal government.

And that is why we confidently claim that the program indeed returns more money than it costs.

What is so special about the EADC program?

Well, to begin with, U.S. manufacturers have really not had a very easy time of it in the last few years, Especially among small and medium-sized manufacturers, adverse effects have been especially painful.

And having said that, I guess I point with a certain amount of almost parental pride to the EADC program as a federally—I'm sorry—as a federally-sponsored project which has been easing the pain of these manufacturers.

The EADC program has done that through this nationwide network of universities. To be specific, there are 13 universities in the program and because they do cross State lines, we are able to claim that we serve realistically all or parts of 36 States.

This extends from Massachusetts Oregon, from Wisconsin to Texas. Moreover, these engineers who participate in this program are sometimes thought of as being rather esoteric. And it might be easy to say why are they interested in these kinds of things.

Ask the manufacturers they serve. The manufacturers they serve tell us because of their integrity, because of their expertise, and most of all because of their objectivity. They have nothing to sell, and neither do we.

The recommendations are made because we honestly believe these are the things that will save money and help.

Small and medium-sized manufacturers are key elements in the national economy, we recognize that, but the biggest problems are uncertainty and risk and all the other problems that flow from those two.

EADC do help to reduce uncertainty and risk and without their intervention, many manufacturers would be much more hesitant to take on projects that are going to, in the long run, save them money. They would be hesitant because it does involve risk and we are dealing with manufacturing operations. Roughly, 70 percent of the savings we achieve are manufacturing operations not in the building envelope, or in the lighting system.

To conclude we think that the EADCs have become rather a vital factor to improve the competitiveness of the manufacturers that they serve. Without federal support though, they will no longer be able to provide their cost-effective recommendations and the manufacturers will have lost a resource of competence, integrity, and objectivity.

With the federal support, with the kind of assistance that the EADCs provide, we think the nation's small and medium-sized manufacturers will be better able to compete, to earn a profit, to stay in business, to purchase and sell goods and services, and to strengthen the nation's economy in the long run.

And I ask you to provide this much needed support.

That concludes my testimony.

[The prepared statement of Dr. Kirsch follows:]

HOUSE OF REPRESENTATIVES
SCIENCE, SPACE, AND TECHNOLOGY COMMITTEE
ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE

February 28, 1989

Testimony prepared by

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University City Science Center

University City **Science Center**

I would like to thank the chair and the other members of this subcommittee for the opportunity to speak on behalf of energy conservation and, especially, energy conservation among small and medium-size manufacturers. I am William Kirsch, director of the Energy Analysis and Diagnostic Center program, an industrial energy conservation program supported by the Department of Energy at a projected rate of about $1.73 million/year.

This program has identified over $400 million in cost savings and more than 82 trillion BTU in energy conservation for small and medium-size manufacturers since its inception 12 years ago. Moreover, we know that, from one year to another during its history, half to three-quarters of the energy-conserving and cost-saving potential has been implemented by these same manufacturers.

What I am asking is for the Congress to continue support at $1.8 million/year of a program which has been generating far more dollars for the federal government than it has cost. However, without continued federal support--the kind of support which is truly seed money--the EADCs cannot survive. Let me explain why federal support is needed and profitable.

The EADC program has two chief goals. The first is to help small and medium-size manufacturers to become or remain competitive by reducing their energy costs through more efficient manufacturing operations. The second is to offer engineering graduate and undergraduate students opportunities to gain practical industrial experience as part of their education.

To fulfill these goals, university engineering faculty and students perform on-site analyses of plants' manufacturing operations and their energy use. They make specific recommendations to improve the plants' efficiency and competitiveness and present these results through individualized reports. My staff and I review all of these reports and verify their results through interviews we conduct in person with a large number of manufacturers. Further, we require these same faculty to find out later how much of what they recommend is actually implemented.

During 1988 my staff and I interviewed 243 of these manufacturers, and here is a brief summary of what they told us:

> The EADC program is a good expenditure of taxpayers' money: 94%
>
> Energy audit reports are considered extremely well done or well done: 93%
>
> Manufacturers agree with all or most of the conclusions expressed in those reports: 88%
>
> Manufacturers are implementing at least some energy-conserving and cost-saving recommendations: 94%.

Because we also find out specifically how much of the manufacturers' energy-conserving and cost-saving potential is implemented, we also know the dollar value of their savings, and we can estimate its taxable value to the federal government. That is why we confidently claim that the federal government's earnings are several times as large as its costs for the EADC program.

It is reasonable to ask what is so special about this EADC program, and I would like to address that question.

U.S. manufacturers have not had a very reassuring experience, on the whole, during recent years. Among the small and medium-size segment of that population, adverse effects have been especially painful. Having said that, I point with almost parental pride to the EADC program as a federally sponsored project which has been easing this pain in an effective manner. The EADC program has done that through a nationwide network of skilled engineers who, with zeal and dedication, have reached out to manufacturers, have identified real problems where and how they occur in the plant, and have proposed practical ways for plants to reduce costs without sacrificing product quality.

Moreover, these skilled engineers who participate in the EADC program are university faculty, graduate students, and advanced undergraduates. Skeptics may not easily credit these people with an abiding interest in real-world manufacturing problems, but over 90% of about 2500 manufacturers have stated otherwise. In fact, they tell us when we interview them, the objectivity and integrity and competence of the faculty and students are major factors in convincing manufacturers to accept the recommendations and implement them.

Small and medium-size manufacturers are key elements in the nation's industrial economy. The manufacturers' biggest problems are uncertainty and risk and all the other problems which flow from those two. EADCs reduce uncertainty and risk, but without their intervention manufacturers are likely to maintain the status quo and not seek assistance of uncertain value and unknown risk.

The manufacturers who have survived the last ten years know what they have to do if they are going to prosper. One need is new technology, but that need can be met only through the application of the technology. It is not enough to discover and develop technology; we also must learn how to apply it effectively.

EADCs have become important links in the application of energy and manufacturing technology--old as well as new. EADCs have become vital factors to improve the competitiveness of the manufacturers they have been able to serve. But very much remains to be done. Without federal support, the EADCs will no longer be able to provide their cost-effective recommendations, and the manufacturers will lose a resource of competence, practicality, and objectivity.

With federal support for the kinds of assistance which EADCs provide, the nation's small and medium-size manufacturers will be better able to compete, to earn a profit and stay in business, to purchase and sell goods and services, and to strengthen the nation's economy. I ask you to provide this much needed support.

PANEL 1 DISCUSSION

Mrs. **Lloyd**. Thank you, Dr. Kirsch, for your testimony, as well.

You discussed the need for the global warming mitigation energy strategy in your testimony, Mr. Ledbetter, but it seems to me if we are really going to make an impact in global emissions, we're going to have to encourage other countries as well to embrace cleaner burning fuels and to be efficient.

Where are we? Where are we in relation to neighboring countries? What are other countries doing?

Mr. **Ledbetter**. Where are we?

Mrs. **Lloyd**. With respect to CO_2 emissions. What are other countries doing in this area?

Mr. **Ledbetter**. What are other countries doing to improve their energy efficiency?

Mrs. **Lloyd**. And to reduce CO_2 emissions.

Mr. **Ledbetter**. There are many industrialized countries that have national government energy efficiency programs in the area of research and development, in the area of standards for new buildings and what not.

The programs are so widespread and varied it is hard to say that this program or this country has better programs than this country.

You can find some countries that have higher research and development spending levels than the United States. But then the same country may not have, for example, standards to improve automobile fuel economy.

If you look at just the efficiency of various countries, you can see that among industrial countries, the United States is among the least efficient. When you compare us with our major competitors, say, like Japan, West Germany, Sweden, the United Kingdom, we are less efficient. We use more energy to produce a unit of economic output than any of these other countries. That puts us at a competitive disadvantage by the way but that clearly is the case with industrialized countries.

With the lesser developed countries, the story is quite mixed there. But, generally, these countries are highly inefficient. And it is because they are using low forms of fuel. They are very dependent on biomass, dung, and what not, and they have low economic output, leaving by the way, plenty of room for improvement in energy efficiency.

So it is hard to make a comparison across the globe saying this country is better off than another. But, clearly, when you compare our efficiency with other like nations, similarly industrialized, we are clearly way back in the pack.

Mrs. **Lloyd**. Well, coming from being a number one industrialized nation, would it be that at this point in time we have older plants?

Mr. **Ledbetter**. That clearly—for example, you are comparing us with Japan or South Korea. Sure. That is certainly a contributor to the efficiency situation. We are just not making the investment in many of these new plants.

And you probably have a comment on that since you work in the industrial area.

Dr. **Kirsch**. I do. Do you mind a comment?

Mrs. **Lloyd**. Please, Dr. Kirsch.

Dr. **Kirsch**. What I find in the field, and I guess I can claim some familiarity, I personally have been in over 900 plants in the last seven years, that is a lot of road-time. But, quite seriously, what I find is that we have not only aging equipment, but industrial efficiency is only—industrial energy efficiency is only one part of the total package.

The total package deals with such questions as investment and leveraged buyouts and a number of other policies which affect industrial actions.

And so many times we find that equipment isn't just aging because people won't spend money, but financial resources are finite and money that might have gone into productive—in the sense of manufacturing productive capital investments, that money has gone into other kinds of business-related activities which do not necessarily improve industrial productivity or energy efficiency.

Mrs. **Lloyd**. Buyouts don't leave money for that type of investment.

Dr. **Kirsch**. Pardon me?

Mrs. **Lloyd**. Some of our buyouts do not leave money for that kind of investment.

Dr. **Kirsch**. That's right. I have been in plants that have had three owners in the last year. And in each—the man you're talking with is saying, "I'm not sure right now whether I am reporting to Chicago, New York or New Orleans." And I am not in any way, you know, singling out those cities as targets. I'm just saying that I have seen that situation.

And so capital investments for manufacturing activities do tend to get put on the back-burner at a time like that.

Mrs. **Lloyd**. What do you think we should do about this?

Dr. **Kirsch**. One of the things that has been proposed, and I can see some merit to this, although I recognize its complexity, is the question of the tax treatment of the financing of the buyout.

I really believe that can create a disincentive, or at least reduce the incentive for the buyout and put it in comparison with other kinds of productive capital investments that manufacturers could make.

Mrs. **Lloyd**. That is a worthy point.

I would like to ask both of you really how you assess how well we are doing in transfer technology. We do have the technology to have the good windows that would improve energy efficiency.

Are we taking the technology that we are developing at our laboratories and our universities and our plants to their full capacity at the marketplace?

How can we do a better job of this?

Mr. **Ledbetter**. I share your concern that we are not involved in the development stage to the point where we should be. We are withdrawing too soon.

This Administration has adopted a philosophy in technology development that requires the federal government to pull out prior to commercialization and prior to demonstration.

Mrs. **Lloyd**. We get to the cutting edge and then we pull back and we don't get to market the technology.

Do you share that feeling?

Mr. LEDBETTER. Clearly. We can find many; many examples of that in the Department of Energy where the Department of Energy has pulled out of technological development before the technology is demonstrated.

And oftentimes the technology then languishes and it's never demonstrated. There is a lot of risk involved in bringing new technology to market, and the government clearly has a role to play in helping bring that technology to market.

Mrs. LLOYD. Dr. Kirsch.

Dr. KIRSCH. I find that manufacturers also look at the people we deal with; the small and medium-sized ones are very concerned with problems of cash flow. And so even though we have the technology, let's say, that can show them savings or potential savings of $40,000 a year on their energy bill, if it takes $200,000 to implement that, they will stand back and look at that very carefully.

So I see a need for increased technology transfer by being sure that we have the transfer capability in the full size range.

In other words, not only that we can do it for the plant with sales of $100 million a year, but that we can do it for the little guy with sales of $18 million a year.

And, for instance, cogeneration is one example where the low and intermediate size of cogeneration units has come about very slowly and manufacturers are looking at this. They do occasionally implement it.

But, of course, cash flow is always a consideration. We see the transfer improving, but I wish it could be faster.

Mrs. LLOYD. Thank you.

Mr. Morrison.

Mr. MORRISON. Mr. Ledbetter, your opening comments I think are right on target with a lot of things that a number of us are looking at in the global warming area.

This Committee, however, finds itself in continuing to invest in the use of fossil fuels.

Are you recommending that we just say that that is not a sound investment? That Clean Coal Technology is something we should abandon at this point?

Mr. LEDBETTER. No, no.

Mr. MORRISON. Or we should invest more dramatically in the replacements for those fossil fuels?

Mr. LEDBETTER. No, I would not recommend that we abandon the Clean Coal Technology Program. But I would recommend that we put increased emphasis on those Clean Coal technologies that improve production efficiency.

Most of my comments focus on end use energy efficiency, improving the efficiency with which we use energy.

On the other hand, we can make just as large—I shouldn't—not magnitude. We can make a substantial contribution to carbon emission reductions if we improve the efficiency with which we produce energy.

And some of these Clean Coal technologies do that sort of thing, and I would recommend that we put increased emphasis on those technologies.

Mr. Morrison. It's not just a matter of scrubbing the SO_2 and so forth out of the air.

Mr. Ledbetter. Getting higher thermal efficiencies.

Mr. Morrison. Higher thermal efficiencies. Okay.

Mr. Ledbetter. Yes.

Mr. Morrison. The heat island example that you used, what are some potential ways of handling that?

You talked about reflective materials. Does that include on sidewalks and street areas?

Mr. Ledbetter. For example, perhaps—and this is an area that would require research, but perhaps we can develop a paving material, say, an asphalt base like we use right now, that contains a much higher reflective material, like some kind of light sands and indications are that that would have a much higher reflectivity and could substantially reduce the microclimate on a parking lot.

You could shade that parking lot with trees. Just an urban tree planting program would be a very important part of addressing the urban heat islands. The City of Los Angeles just made a major commitment prior to the Olympics to plant one million trees. They pulled it off and within the last few months they made a commitment to plant five million trees.

Now, they are banking on this being a successful program and that it will help mitigate the urban heat island effect. But, as I was stressing earlier on, these are only preliminary indications that we have in this research; not nearly enough research has been done to characterize the problem to make certain that we are doing the right sort of thing.

So, tree planting and white paint on buildings, roof paints that include aluminum powders—there are just all kinds of measures that we can take to improve the reflectivity of building surfaces and substantially reducing urban temperatures.

Mr. Morrison. Thank you.

There obviously are some practical answers out there.

You mentioned that we weren't ready on glass standards yet. Is someone working in that direction so that we could adopt a national standard?

Mr. Ledbetter. Yes. There are a number of industry organizations that have standards for various glass properties. There is an organization called the Primary Glass Manufacturers Council. And they have recently come out with standardized test procedures for the emissivity of a window, which is a—it is an energy performance characteristic that is very important in determining the energy effects of these windows.

But there are all kinds of parameters—shading coefficients, thermal conductivity—all kinds of parameters that need to be standardized throughout the industry.

I recently met with representatives of many of these industry organizations in Chicago to discuss this problem. And the industry sounds very interested in this sort of thing. They had not made final commitments yet but there are many of these industry organizations that think that it is time to establish a level playing field so that the window manufacturing industry can have valid comparisons among window products.

Everybody right now just uses the testing procedure of their preference. And sometimes one test procedure is more beneficial to one category of windows than another.

And so it is really a hodge-podge of test procedures that we have out there.

The other very important part of it is that we want to see a label developed that has more information on it than just the shading coefficient or the emissivity because the majority of small builders will not be able to use those sorts of numbers. It is only the sophisticated architectural/engineering firms that will be able to use those numbers.

Well, so we want to see an energy performance value assigned that assumes certain operating conditions for a window.

And says, for example, for purposes of national labeling we are going to assume a climate that is similar, say, to Dallas, Texas. And that this window will be located on the north side of the building. And the internal temperature will be 70 degrees. And then through modeling that window in a similation program, we will be able to come up with some sort of energy performance value. And maybe we will come up with a value that is on a scale of one to ten.

And then that value can be used by local building code officials all over the United States that are starting to get involved in this area of specifying various window types.

It can be used by window buyers. We just need a standardized national value like that, that will help level the playing field.

Mr. **Morrison**. Sometimes, of course, that is done by industries themselves. Get together and established a standard.

I think your recommendation is that we standardize this from the federal perspective.

Mr. **Ledbetter**. What I think would be the best track to take would be for the federal government to do the research that is necessary to support the labeling program and that the industry itself should administer and enforce the labeling program.

I think there is very strong interest in the industry to do that sort of thing. If that fails, then I think we ought to look at the federal government administering the labeling program. But I think they're interested in this enough to take it on themselves. They don't want to take on the research themselves because, first of all, the Department of Energy has better expertise in this area. They have a wonderful research group out at Lawrence-Berkeley in California that can help them develop this sort of thing.

And I think they are seen as an objective player in this area, that will not tilt toward any one part of the industry.

Mr. **Morrison**. Thank you. And also your list of your priorities in the back of your presentation will be very helpful to us. Thank you.

Mr. **Ledbetter**. Thank you.

Mrs. **Lloyd**. Mr. Wolpe.

Mr. **Wolpe**. Thank you very much, Madam Chairman.

I have a real sense of dejavu. The last time I was on this Committee, some six or seven years ago, we were very much engaged in a debate over how to allocate R&D dollars among the various alternative energy technologies. And the Chair, in her opening statement, noticed the tremendous reductions that were taking place in this year's proposed energy budget for conservation, and for conservation and renewable energies, from $58.2 million, a reduction in the case of conservation for last year's numbers; 26 percent decrease in the case of renewables.

But that is against the backdrop where we were at $400 million, roughly, apparently, in the 1980 area for conservation; and $700 million for renewable energy activities.

So that we really have decimated the program over the years. It is a mystery. It is a puzzlement how that could have happened given the analysis that you have offered today, which has been I think valid throughout this period of time, which has indicated that the cheapest, most cost-effective means of displacing our dependence upon petroleum were investments in efficiency and renewables.

I'm really responding in part to the question that Mr. Morrison was raising just a moment ago about how do we allocate resources in terms of fossil fuels, in terms of nuclear, in terms of all of the options out there.

And I think, like you suggested, it is not necessarily a case of eliminating some of our work in Clean Coal Technology, because I think there are some important gains that can be achieved there, but if those investments are coming at the sacrifice of that—which yields the quickest, most rapid displacement of our dependence upon fossil fuels—then something is clearly wrong.

And I guess I hope that this Committee would in its deliberations as we try to come to term with the overall Energy R&D Budget begin to try to identify some objective criteria, because what has happened historically—at least it has been my experience—that we make these decisions not on the basis of any objective criteria, of how we might most critically displace our dependence upon fossil fuels most cheaply, but rather upon, frankly, who has the most political clout.

And also the big ticket items tend to take the lion's share of the activity because they have the largest lobbyist organizations in place.

And that is the context in which I would like to ask a few questions. We need to upgrade our knowledge in order to achieve some ability to argue this from the standpoint of some objective economic criteria.

Back in the early eighties, we had numbers that indicated that X-investment in residential conservation would yield so much displacement of petroleum at such and such a value, of cost.

And we could do the same for transportation sectors and for the industrial sector. And I wonder if either of you can supply today some upgraded numbers that would give us some sense both of potentials yet to be achieved within each sector of economic activity—residential, industrial and transportation—and the kinds of investments that would yield displacement of petroleum or fossil fuels more generally.

Mr. **Ledbetter**. That could take a while to answer. But let's see if I can summarize it.

You asked what kind of potential is left in the various economic sectors we have. And there have been quite a number of studies done on this, looking at the technological and economic potential for improving energy efficiency in various sectors. And most of the studies end up centering in the residential and commercial areas on potential savings of, say, 30–50 percent.

In the industrial area, there is a little less, say, on the order of 30 percent. That is largely due to the fact that the industrial sector has done a better job in improving its energy efficiency over the last decade and a half than the commercial and residential sector.

And also because just the economics that drive efficiency improvements are stronger in that sector than in the residential and commercial sector. The cost of energy is a much larger part of doing business in many industrial businesses than in, say, in operating a commercial building.

So there's much more attention focused on it. So that is the potential, and you asked for?

Mr. WOLPE. Transportation as well.

Mr. LEDBETTER. Excuse me. Transportation.

Transportation, I cannot think of a number right offhand, but if we look at automobiles, we are presently at an average fuel economy for automobiles of around 28.5 miles per gallon. And there are many experts who have taken a close look at this area and they have said that we can get to 50 miles per gallon and higher. And that would be a cost-effective and technologically achievable level.

With other areas of transportation, we have done much better with airplanes. We have seen a substantial improvement in the efficiency of jet aircraft. I am not familiar with numbers in the other modes of transportation—railroads, marine vessels and what-not.

I don't know what that all adds up to but, clearly, there is substantial—the majority of energy in the transportation sector is used by light vehicles. I think it is two-thirds of all energy in the transportation sector is used by light vehicles, light trucks and automobiles. And we clearly can come close to doubling the fuel economy of the vehicles that we have out there with the current prices we have for gasoline.

So there is a huge opportunity there.

You asked for some examples of technologies that would get us there.

Mr. WOLPE. Yes.

Mr. LEDBETTER. There are literally hundreds, if not thousands, of technologies that could be implemented that are now commercially available that are not implemented because of weak economic signals.

For example, in the residential sector, there are condensing gas furnaces. There are high-efficiency central air conditioners. Air conditioners that have efficiency ratings of 15—I don't know if I want to get off on a side-track and explain how appliances are rated for their efficiency.

But, let's say new, high-efficiency air conditioners can be 50 percent more efficient than the common ones that are used throughout the residential sector.

We have low emissivity glass that is expanding, like I said earlier, but could be used much wider. Just better insulation techniques.

We know that insulation works; we've gotten a lot better in recent years in learning how to install insulation in buildings. It works. It is very complicated.

You may have heard the term "super-insulated buildings". That is a type of building that is highly insulated for a typical size residential building, say, of 2,000 square feet in a northern climate like Montana. It could have an energy bill of less than $200 per year.

And that is not some kind of freakish looking house. It is a very ordinary looking house. You cannot distinguish it from anything else on the street. But the way the building is weatherized is very complicated. You have to pay attention to all kinds of things like moisture and those sorts of things.

So we could take a much closer look at weatherization—insulation techniques in our existing buildings. That is just the residential sector.

In the commercial sector there is a tremendous amount that we can do with lighting. There are all kinds of improvements that are commercially available now that would enable us to reduce lighting, energy use in commercial buildings by about 50 percent.

In the industrial sector there is a tremendous amount that can be done with motors. The majority of electrical energy consumption in the industrial areas, in electric motors, we can substantially increase the efficiency of the electric motors.

And we can use variable speed drives on those motors to better match the loadput on the motors.

The list goes on and on. I guess I'd better stop.

Mr. **Wolpe**. Many of the items you just identified are already developed and are past the research phase and are either already commercially available or could be commercially introduced.

What role can the government play at this stage in terms of facilitating the introduction of some of those technologies. For example, I don't think we have done very much in the way of federal procurement or the establishment of federal standards for certain kinds of construction that might take place.

Mr. **Ledbetter**. Sure. The ideas you suggested are certainly good ones. One of the ideas is the one that I presented a little bit ago—the window labeling. That should help that kind of technology grab a larger part of the market. We could help in all kinds of ways in technology transfer, helping architecture grow and engineering firms to develop the computer tools that will improve their ability to design buildings that use these kinds of technologies.

Many of the computer tools that they have now that they are using do not include some of the—many of the technologies that are now available.

So there is a lot that can be done in the technology transfer area. There is a lot that can be done in just developing model standards that the federal government just issued, some model commercial building standards that will be mandatory for the federal government and that will be voluntary for private industry.

There are things we can do in the regulatory area. A lot of these ideas are contained in a book that my organization just published last year.

We've recommended 26 specific actions that the federal government could take to improve energy efficiency in the United States.

And they range from research and development technology transfer, regulatory actions, standards, technical assistance to utilities, State government agencies.

The area of technical efficiency assistance is important. There's a lot that can be done.

Dr. **Kirsch**. May I make a comment? I would like to comment that in our limited sector dealing with small and medium-size, I am talking about what appeared to us relatively large numbers. But, remember, we have served a total—over 12 years now, we have served a total of only 2,500 small and medium-sized manufacturers.

There are approximately 300,000 in the country. So we are much more attuned to tech transfer and technical assistance. And there is a tremendous amount still to be done.

People are doing things, but they get to a stage where they don't know whether to go this way or that way. They have no objective advice. And so they tend to do nothing under those circumstances.

And this is where we try to move them on. For example, in the specific topic of energy-efficient motors, we point out to manufacturers don't look at the total cost of that high-efficiency motor, look at the incremental cost if you are replacing it. You have to have some motor. Look at the incremental cost, not the total cost.

Also remember, if you rewind the old one, you are going to lose at least 5 percent of its efficiency every time you rewind it.

So that is the kind of thing. We are not selling motors, you see, and to the manufacturer that does carry certain amounts of credibility that we are trying to show him how to look at these things in terms that make sense to him in his planning.

Mr. **Wolpe**. The thing I worry about as we approach this year's budget cycle is that we have had a series of reductions over the last several years here, not only in this section but across the board, particularly dramatic reductions in these areas.

I'm afraid we are locked into assuming that reduced budget because it is so hard to reverse the scale of downward reductions that have occurred across the board.

And, yet, if the efficiencies are as indicated, the economic efficiencies—or let me say a better word in this instance. If the economies are what are valid here, as has been suggested, and if we have to address now the broader environmental set of concerns as it relates to the Greenhouse Effect, the ozone depletion, and the like, then it seems to me nuts to be tied into the assumption that we have to operate within the $149 billion range for renewables, and some $115 billion for conservation. I just don't understand the logic of that as it relates to our national interests for the future.

I say that because even you in your own testimony seemed to assume that those parameters.

Mr. **Ledbetter**. I guess I have been beat back into submission over the years. We come up here and ask for money every year and don't get it, so we fall into the same path everyone else has taken. I refer to my testimony to the piece of legislation that was introduced by Representative Claudine Schneider.

I think she has a very important concept in that bill for deciding how we should allocate our energy investment dollars in the federal government. The concept is just borrowing from an idea that is being used increasingly in the utility industry now. And that is the concept known as Least Cost Planning.

That concept is in the bill and it says we should allocate our dollars in the federal government to those energy technologies in those areas that show promise of delivering us energy resources either in the form of new supplies or in conservation at the lowest possible cost, taking into account of course environmental measures, environmental effects and others.

But there is a good way of approaching that morass and trying to give some rhyme and reason to it.

Mr. **Wolpe**. I agree entirely with that. I don't know what studies exist that lay that out in an updated form that would try to take that measure, but I wonder if the Committee staff also might be of assistance to the Committee in attempting to generate that kind of analysis for us.

We might get a sense of what we are talking about here in terms of R&D dollars that we're putting up front and the end product that we hope to achieve.

Mrs. **Lloyd**. If the gentleman would yield, his point is well-taken. But if you look at the levels recommended by the Department of Energy in these areas, and see what we have done through this Committee in upping the funding, I think we have done a credible job in improving the recommendations from the Department of Energy.

Mr. **Wolpe**. Oh, I know, it has been a struggle. I am greatly appreciative of what you have done over the last several years to minimize the damage. But the fact of the matter is, all those struggles notwithstanding, and, incidentally, in my other Committees, we have been no more successful, so I am not being critical here, but we have just kind of high priority investments have been greatly reduced to the detriment of our national interests. And other kinds of investments have been increased. And the subsidies going to other kinds of technologies and minimizing our ability to do what would make a greater difference. That's my concern.

But, I thank the Chairman for what she has done in trying to resist some of these very detrimental things.

Dr. **Kirsch**. I would like to thank this Subcommittee and the Congress for keeping us alive. We have had a zero dollar request every year.

Mr. **Wolpe**. I realize that. I don't mean to be too critical of us.

Mrs. **Lloyd**. We have to look at where we've been and where we're going.

Thank you, Mr. Wolpe and thank you, Mr. Ledbetter.

Thank you, Dr. Kirsch.

You were excellent witnesses.

[Panel excused.]

Mrs. **Lloyd**. Our second and final panel consists of Eric Hirst from the Oak Ridge National Laboratory, Mr. James W. Patten is from Cummins Engine Corporation and Ms. Susan Stone representing the National Association of Regulatory Utility Commissioners.

Welcome, panelists.

Mr. Hirst, I have been delighted at the references to Oak Ridge National Laboratory by our previous panelists and witnesses. The good work that is being done at Oak Ridge in energy conservation and you are a part of that picture and I am just delighted that you're here. And I'm also proud of the fact that I can be your Representative.

Please proceed.

Mr. HIRST. You have at least one vote here.

Mrs. LLOYD. And that's a part of the record, folks. [Laughter.]

PANEL 2

STATEMENT OF ERIC HIRST, ENERGY DIVISION, OAK RIDGE NATIONAL LABORATORY

Mr. HIRST. I am pleased to have a chance to talk to this Subcommittee about the benefits of DOE's Conservation R&D and Programs and the need to expand such efforts.

Before suggesting some specifics about an expanded federal role, let me provide some background.

First, I think I will talk about the benefits of improved efficiency. By far, the most important benefit is the direct dollar savings to all energy consumers, which amounts to about $150 billion a year.

In addition to these individual benefits, there are large social benefits that accrue. Benefits related to improved economic productivity, and international competitiveness, environmental quality, and energy security.

These are issues that have been discussed frequently in the past, but there are a couple of others I think that haven't been raised. Those have to do with the public concerns.

The public is deeply, and has been for quite a while, concerned about environmental problems. The public recognizes the strong link between improved energy efficiency and environmental quality.

And a recent survey showed that the public strongly favors greater federal government expenditures on energy efficiency over any U.S. fuel source.

Mr. Wolpe asked Marc Ledbetter some questions about the future potential. Marc answered by giving some sector-specific examples. A recent DOE estimate suggested that the savings that could be achieved in the year 2000 amount to 20 quads beyond what we are already achieving. That represents an additional savings of about 20 percent of U.S. energy use.

The Lawrence-Berkeley Laboratory did another study that estimates a potential saving in the year 2000 that is even larger, amounting to about $200 billion a year, an absolutely astonishingly large amount.

This potential includes a lot of things. More widespread adoption of known technologies, prompt commercialization of new technologies, exploration and development of new ideas and identification of opportunities that are not yet even envisioned.

It is important for the Department of Energy to work on our parts of the lifecycle development of technologies. DOE needs to work on market acceptance and program implementation as well as technical issues.

We are all aware of the federal deficit and how that has constrained the DOE budget. But I think before we accept that we ought to recognize the enormous and positive return on the government's investment in DOE energy conservation R&D.

Marc Ledbetter mentioned one study that showed the payoff to the government's investment. DOE itself did a study a couple of years ago that looked at 35 R&D projects funded by the Department of Energy. These projects cost the government a total of $92 million.

As of 1986, these projects were saving $350 million a year. That savings increases and continues year after year. So the benefit to cost ratio is absolutely astonishing.

It is also important I think to compare the costs and benefits of DOE's conservation programs with those of other federal activities. I have several examples in my written statement. I would like to mention two of them:

The budget for the Agricultural Extension Service is almost 100 times that of the Energy Extension Service—$350 million versus $4 million.

I don't want to criticize the Agriculture Extension Service, but I think it is important for Congress to ask about the relative benefits of those 2 programs and whether those differences justify a difference of 100/1 of agriculture over energy.

One B1 bomber, a single airplane, costs almost double the entire DOE Conservation R&D budget—$280 million versus $156 million.

Again, I am not in a position to criticize the Defense budget, but I think it is appropriate to ask about those comparisons and whether we are putting our priorities where we ought to, as Mr. Wolpe mentioned before.

The Congressional Budget Office recently issued a report suggesting 149 areas in which government funding could be cut.

My written statement suggests six different areas in which the DOE can contribute to national energy efficiency goals. I will just list them and then discuss those that relate most directly to the Subcommittee.

The first, and in some ways the most important, I think, is to sustain a national commitment to efficiency improvements to try to put behind us the eight years of divisive and destructive battles between the Administration and the Congress over the role of the federal government in improving energy efficiency.

The second—the one that I will return to—is to stabilize and increase the funding for DOE's conservation R&D programs.

Third is to increase technical assistance to State and Local governments in electric, gas utilities and to, hence, technology transfer to manufacturers.

The fourth is to improve coordination within the Department of Energy between DOE's Conservation R&D and DOE's state and local programs.

The fifth is to revisit efficiency standards, building standards and the automobile fuel economy standards.

And, finally, I think there is a need for, and an opportunity, to review and update DOE's state and local assistance programs.

Let me talk about a couple of specific R&D examples. I was pleased to hear John Berg in his testimony talk about three different Oak Ridge projects that we are very proud of, as apparently he is: the triple effect gas-fired absorption chiller; buildings foundation design handbook and alternative refrigerant to CFCs that would not emit carbon.

Let me talk about two others, and I have purposely picked fairly small, discrete projects because I want to emphasize the range, the diversity, the variety of DOE Conservation R&D.

The first example has to do with radiant barriers. Basically, paper with aluminum foil on either side of it that is installed in the attic of single-family homes. There is experimental work conducted at Oak Ridge National Laboratory placing these barriers in the attics of homes in Knoxville, Tennessee.

With DOE and TVA funding, measurements were made of the reductions in heating loads in the winter and cooling loads in the summer with and without these radiant barriers.

Two years of experimental data showed savings up to 21 percent in the summer and half that much in the winter. Installing this kind of a radiant barrier in east Tennessee would pay back the investment in reduced electric bills in about five years.

Since these energy tests proved to be so positive, additional tests were done on the effects of dust and moisture on the radiant barriers. Current work at Oak Ridge involves computer modeling to simulate the heat flows through the attic of the house, so that this experimental work can be extended to other climates beyond east Tennessee.

What I think is important here is that the technical competence, professional integrity and the impartiality of the National Laboratories lends credibility to the kinds of research that I am reporting here; because research at Oak Ridge is well-respected and well-done, manufacturers, building code officials, and builders themselves are quite likely to accept the results as legitimate, accurate and credible.

The second example I would like to give has to do with the least cost utility planning program, and I will say just a little about it because Susan Stone from the Illinois Commerce Commission will talk more about it.

To me, DOE's LCUP program is a wonderful example of effective technology transfer, something that I know that you are very interested in. It's technology transfer that doesn't involve pieces of hardware, but rather involves information, ideas; what we have up in our heads that is real important.

For example, Lawrence-Berkeley Lab prepared state of the art reviews on several energy-efficient technologies and programs, including commercial cool storage and lighting.

We at Oak Ridge reviewed the methods that electric utilities use in their planning for future resource acquisitions and how they treat uncertainty.

The National Association of Regulatory Utility Commissioners sponsored a wonderful conference last spring on least cost planning and is sponsoring another conference later this fall.

All of these DOE-funded activities help by compiling, assessing and distributing valuable information to utilities and state regulatory commissions, information that no one commissioner, no single utility, could collect or obtain on its own.

I have got other examples in my written testimony on alternatives to CFCs that do not emit carbon, invent thermally-activated heat pumps and improved energy audit that is now used in DOE's low-income weatherization assistance program.

In conclusion, let me say that the benefits of conservation programs are individually small and cumulatively very large. The number and diversity of energy end uses, market segments, conservation technologies and program and delivery systems lends terrific strength and resilience to our energy system. This variety provides insurance that could not possibly be obtained with the large projects such as an oil refinery or a 1,000-megawatt coal plant.

As I mentioned before, there are lots of reasons to increase DOE conservation funding. As the Quaker Oats commercial says, "It's the right thing to do, and I hope you will."

[The prepared statement of Mr. Hirst follows:]

NATIONAL ENERGY EFFICIENCY OPPORTUNITIES FOR THE 1990s

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Prepared for
Subcommittee on Energy Research and Development
Committee on Science, Space and Technology
U.S. House of Representatives

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The primary purpose of this testimony is to suggest roles and responsibilities for the federal government in improving energy efficiency throughout the U.S. economy during the 1990s. The growing recognition of the threats to our global environment posed by carbon dioxide and other pollutants and the start of a new administration provide fresh opportunities as well as challenges. The federal government can and should play a major role in catalyzing efforts to improve energy efficiency, the only short-term way to reduce carbon emissions and the threat of global warming (Fulkerson et al. 1988).

Valuable federal actions include vigorous support of energy efficiency by the President and the Secretary of Energy, agreement between the Administration and Congress to sustain a long-term federal commitment to energy efficiency, expanded funding for Department of Energy (DOE) R&D projects, increased technical assistance from DOE to state and local governments and utilities, improved coordination between DOE R&D programs and DOE state and local programs, additional support for energy-efficiency standards, and a thorough review of DOE's state and local assistance programs.

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2

BENEFITS OF IMPROVED ENERGY EFFICIENCY

Much has been written about the many benefits to improving efficiency. The most obvious gain from efficiency improvements is the economic savings experienced by households, businesses, manufacturers, and farms that adopt energy-efficiency measures. The U.S. economy is saving at least $150 billion a year because of these efficiency gains (Mills et al. 1988). Beyond these direct benefits, society gains in three important areas: environmental quality, economic competitiveness, and energy security (Chandler, Geller and Ledbetter 1988).

To a remarkable degree, the public recognizes these benefits and has shown a strong and continuing interest in environmental quality and a clear preference for energy-efficiency resources over supply alternatives. **Project 88**, a study commissioned by Senators Wirth and Heinz (Stavins 1988), cites several publications showing that "Public demand for a quality environment is strong and deep. Public opinion polls consistently show that public concern over environmental quality has remained firm during energy crises, economic downturns, and tax revolts."

A nationwide telephone survey of 1000 adults, conducted in September 1988 (The Analysis Group 1988), showed much stronger support for resolving energy problems by "encouraging energy efficiency" (64%) than by "encouraging greater energy production" (29%). Three-fourths of the respondents believed that "more efficient use of energy" should play an extremely important role in meeting America's future energy needs, much higher than the percentages that favor American-produced oil (59%), natural gas (49%), nuclear power (31%), or coal (27%). When asked to choose the single most important energy resource on which the government should spend more money, 41% chose solar energy, 25% chose energy efficiency, and no more than 10% chose nuclear power, oil, coal, or natural gas (Table 1). Large fractions of the respondents "strongly favor" government standards mandating improved automobile fuel economy (61%), energy-efficiency standards for construction of new buildings (60%), and new regulations and incentives requiring utilities to help customers conserve energy (48%). Much smaller percentages strongly favor more nuclear plants in the U.S. (14%) or a 30 ¢/gallon increase in gasoline taxes (7%).

Thus, the American public is deeply concerned about environmental problems, recognizes the strong links between energy production and pollution, favors energy efficiency over increased production by a two-to-one majority, and favors greater government expenditures on energy efficiency over any indigenous fuel source by at least two-to-one.

Table 1. Responses to September 1988 telephone interview question: If you had to choose, which one would you have the government spend money on in order to meet America's future energy needs

Solar energy and other renewables	41%
Energy efficiency and energy conservation	25
Nuclear power	10
American produced oil	10
Coal	6
Natural gas	5
None or don't know	3
Total	100%

Source: The Analysis Group (1988).

PAST PROGRESS AND FUTURE POTENTIAL

Several analyses (Hirst et al. 1983; Geller et al. 1987; Klan 1988) document the enormous improvements in energy efficiency achieved during the past 15 years. Mills et al. (1988) estimate that efficiency improvements cut energy use in 1986 by one-third (27 Quads) relative to 1973 efficiency levels, reducing our nation's fuel bill by $150 billion.

Although energy use per unit of GNP declined steadily from 1973 through 1986, the last two years have seen little progress. National energy productivity is stagnating because of low fuel prices, increasing production for some energy-intensive industries, and slowing efficiency efforts.

Although substantial improvements in energy efficiency were achieved during the past 15 years, the well is far from dry. Mills et al. (1988) estimate "that a $200 billion annual conservation potential remains untapped." A recent DOE project (Pirkey and Scheer 1988) reviewed several earlier studies of conservation potential and concluded that the potential for cost-effective conservation in the year 2000 is nearly 20 Quads (a 20% reduction relative to the Energy Information Administration forecast).

This enormous potential for additional energy savings is made up of many small improvements. These improvements include wider applications of known technologies, prompt commercialization of new technologies, exploration and development of new ideas, and identification of opportunities not yet envisioned. Carlsmith's (1988) testimony before this Subcommittee identified several examples of important research at Oak Ridge National Laboratory (ORNL), including:

- Development of a new form of intermetallic, nickel aluminide that retains its strength at very high temperatures,

- Completion of the High Temperature Materials Laboratory, a focal point for developing ceramics and other high-temperature materials,

- Completion of the Roof Research Center, used to design and test the thermal performance of roofing systems for commercial and industrial buildings,

- Development of data-collection procedures to determine the performance of retrofits for residential and commercial buildings, to enhance transfer of information on retrofit performance.

Technological opportunities exist for most end uses, including fossil-fuel powered heat pumps, advanced electric heat pumps, high-efficiency electric motors and controls, industrial cogeneration, new automotive engines and drivetrains, and new lamps, fixtures, ballasts, and lighting controls for commercial buildings.

The government's role in encouraging households, businesses, and industries to adopt known efficiency improvements is as important as its role in developing new technologies. A recent Oak Ridge project involved development of a new energy audit for low-income homes. The audit was field-tested in Wisconsin; results with the new audit showed a substantial decrease in retrofit costs and a substantial increase in measured energy savings, improving productivity of the low-income program from an annual savings of 5 MBtu per $1000 invested to a savings of 13 MBtu/per $1000. This Oak Ridge audit is now used throughout Wisconsin, in Pennsylvania and in New York, saving money for the federal government and reducing fuel bills for low-income households.

BUDGET CONSTRAINTS

Although there are immense opportunities to reduce U.S. energy use cost-effectively; although adoption of these measures and practices would yield substantial indirect benefits associated with environmental quality, national security, and economic productivity; although much of this potential will be realized only with federal involvement; although the return-on-investment from DOE's past conservation R&D has been enormous; the federal budget deficit is seen by many as an insurmountable obstacle to increasing the DOE conservation budget.

Before this Subcommittee accepts the idea that additional funding for energy conservation R&D and programs is infeasible, it might review government expenditures on other programs (Table 2). For example, the Agricultural Extension Service spent $358 million in FY-1988 (U.S. Dept. of Agriculture 1988). According to the Department, "The Extension Service, in partnership with the States, coordinates and supports programs in information delivery and technology transfer. Programs assist individual and communities in identifying and solving farm, home and local problems ... ," words that could equally well describe the Energy Extension Service. During the same year, DOE's Energy Extension Service spent $4 million, roughly 1% as much as the Agricultural Extension Service.

Much has been written recently about the tremendous cost of new weapons systems; see, for example, the cover story of the January 23, 1989 issue of **Newsweek**. A single B-1 bomber is estimated to cost $280 million, nearly double the annual cost of the entire set of DOE conservation R&D programs in transportation, residential and commercial buildings, and industry.

Finally, the federal government's annual fuel bill is $8.3 billion. But DOE's Federal Energy Management Program, which is charged with reducing this bill, has a budget of only $1 million a year. The federal budget for retrofitting its buildings is $54 million a year, a tiny fraction of the amount that could be profitably invested. Increasing the federal retrofit budget by a factor of ten would, over the next 10 to 20 years, save money for the federal government, reduce U.S. energy use, and demonstrate the performance of new technologies to the private sector.

The point of these comparisons is to ask whether we aren't being "penny wise and pound foolish" in allocations of research and program funds to DOE's conservation efforts. Improving energy efficiency will save money for the federal government, increase economic growth (and federal tax revenues), and improve our health by reducing environmental emissions (thereby cutting federal expenditures on medical programs). A recent study noted that 35 DOE conservation R&D projects, which cost $92 million, were already saving $350 million a year in fuel costs as of 1986 (Brown 1988).

SUGGESTIONS FOR FUTURE FEDERAL ACTIVITIES

SUSTAIN A NATIONAL COMMITMENT TO EFFICIENCY IMPROVEMENTS

After World War II, the U.S. made a major, long-term commitment to development and commercialization of nuclear power. We created the Atomic Energy Commission, established the congressional Joint Committee on Atomic Energy, expanded the national laboratories, and spent billions of dollars to make nuclear power a reality. This resolution

Table 2. Comparison of various federal expenditures (million dollars in FY-1988) with Department of Energy expenditures on energy efficiency

Department, program and budget		DOE conservation comparison	
Agriculture			
Agricultural Extension Service	$358	Energy Extension Service	$4
Defense			
One B-1 bomber	280		
One Trident submarine	1500	Conservation R&D	156
Space (NASA)			
Space and transportation systems	1143	Conservation R&D	156
Nuclear Regulatory Commission			
Nuclear safety research & regulation	401	Conservation regulatory research	~3
Federal fuel bill			
Buildings & facilities	4000	Federal Energy Management Program	1
Transportation (mostly DOD)	~ 4300	Federal retrofit	54

Source: U.S. Office of Management and Budget (1988).

was sustained for roughly three decades. A similar commitment was made, during the late 1950s and 1960s, to our space program.

During the past eight years, our national energy-efficiency program has been subject to astonishing disagreements between the Administration and the Congress. Each year the Administration proposed decimating cuts in the DOE conservation budget, many of which Congress restored. In spite of this Congressional effort, DOE's conservation budget is less than a third of its 1980 level (measured in terms of inflation-adjusted dollars). If we are serious about reducing carbon emissions, improving environmental quality, enhancing industrial productivity, reducing dependence on oil from the mideast, then the federal budgets for energy-efficiency programs and research should reflect that commitment in terms both of size and stability.

None of the past four Presidents (and Secretaries of Energy) explained to the American public why energy efficiency is important. Presidents Nixon and Ford were largely indifferent, President Carter inappropriately emphasized the deprivation associated with cutbacks rather than the gains associated with technical efficiency, and President Reagan was hostile to a government role in promoting energy efficiency.

President Bush, Secretary Watkins, and Congressional leaders need to help us understand that improving efficiency is good for us individually, good for the nation as a whole, and a wonderful expression of yankee ingenuity that lets us do more with smaller energy inputs. Our federal leaders can reinforce the positive views Americans hold towards energy efficiency (Table 1) and help transform those attitudes into action.

STABILIZE AND INCREASE DOE ENERGY CONSERVATION R&D BUDGET

The past 15 years have been volatile and stormy for federal energy conservation research. During the early 1970s, the very small federal R&D program focused on technology assessment. During the mid and late 1970s, the spotlight shifted to technology development, with a strong emphasis on short-term development and demonstration.

A dramatic change occurred in 1981. The administration sought to abolish DOE and was especially opposed to the conservation program. Although the administration's stated goal for conservation emphasized long-term, high-risk R&D, repeated efforts to slash funding and move staff within and among offices led to chaos and near paralysis within DOE's conservation office. During the past few years, the conservation R&D budgets and programs have stabilized somewhat, although at much lower funding levels than existed in 1980.

Congress should work with the administration to ensure a stable DOE conservation R&D program - stable in funding, focus, and government support. Modest increases in funding would permit many R&D programs to make faster progress and would permit the initiatives proposed by DOE and the national laboratories to begin. These initiatives would use new computer hardware and software to create tools to aid architects, builders and others design energy-efficient buildings; improve the design and construction of manufactured buildings; use federal buildings designed or retrofit under the FEMP program as laboratory and demonstration facilities; develop substitutes for chlorofluorocarbons (CFCs); improve power supplies for advanced lighting sources; expand research on energy use and efficiency in attics and foundations; enlarge the Least-Cost Utility Planning Program to work more closely with utilities and state regulatory commissions; identify market barriers that prevent adoption of cost-effective efficiency measures and develop ways to overcome these barriers; and provide research support for the Low-Income Weatherization Assistance Program.

A project proposed by ORNL would expand initial studies to develop energy-saving ozone-safe refrigerants to replace CFCs now used in air-conditioning and refrigeration equipment. This project would measure the engineering properties of promising new refrigerants, screen and evaluate innovative refrigeration processes that use these new refrigerants, laboratory-test promising refrigerants and systems, and work with manufacturers to speed commercialization of attractive alternatives. The non-CFC alternatives developed through this initiative would not contribute to global warming and would save energy in air conditioning and refrigeration systems.

Another exciting project involves continued development of thermally activated (natural-gas driven) heat pumps. Several such systems are under development, with DOE funding, at ORNL and several manufacturers, including Carrier, Phillips, and Trane. The potential exists to double the energy efficiency of gas-fired heating systems, leading to a potential savings of enough energy to heat 14 million homes a year. In addition to saving energy, thermally-activated heat pumps emit less CO_2 than either conventional gas systems or electric heat pumps.

INCREASE TECHNICAL ASSISTANCE TO STATE AND LOCAL GOVERNMENTS AND UTILITIES

Congress should encourage DOE to work more closely and cooperatively with its "trade allies," those organizations that actually implement efficiency improvements. For example, my work for DOE's Least-Cost Utility Planning Program brings me into frequent contact with people at electric utilities and state Public Utility Commissions throughout the country. I am struck, over and over, with the duplication that occurs. Commissions conduct investigations and issue orders with insufficient knowledge of similar activities in other states. In the same fashion, many utilities estimate conservation potentials and develop programs without a good understanding of what other utilities have learned. Staff at ORNL and at Lawrence Berkeley Laboratory are assisting commissions in New York, North Carolina, and Georgia in developing and reviewing least-cost plans; however, our participation with states is limited by funding.

Although DOE's conservation programs already include effective technology-transfer strategies (Brown 1988), increases in DOE funding for technology transfer would provide substantial savings for other organizations and would speed widespread adoption of efficiency improvements. Additional funding would permit DOE to provide more technical assistance (e.g., develop a Building Efficiency and Conservation Network). In addition, the many legal and procedural barriers to increased collaboration with other organizations need to be reduced.

Additional efforts are needed to encourage greater government-industry cooperation (e.g., The National Competitiveness Act of 1988, introduced by Representative Lloyd) and to recognize that technology transfer includes people and their ideas as well as hardware and software (Soderstrom and Prosser 1988). Such efforts include reduction in the legal barriers to greater cooperation (e.g., requirements associated with advance payments, indemnification, and liability) and reductions in the cumbersome and time consuming paperwork required to negotiate government-industry agreements.

IMPROVE COORDINATION BETWEEN DOE R&D PROGRAMS AND STATE AND LOCAL PROGRAMS

The programs managed by DOE's Office of State and Local Assistance Programs represent potentially valuable mechanisms to implement new technologies and analytical procedures developed by DOE's conservation R&D programs. The low-income energy audit developed at Oak Ridge, discussed above, is a good example of how DOE R&D can be transferred to the field through state and local programs. Additional research support from DOE's Office of Buildings and Community Systems could increase the energy efficiency (and reduce the annual fuel bills) of federally assisted public housing and of homes served by the Low-Income Weatherization Assistance Program.

REVISIT FEDERAL BUILDINGS ENERGY PERFORMANCE STANDARDS

There has been sufficient experience with energy-efficiency standards throughout the country (especially in the Pacific Northwest) to examine anew the federal government's role in improving the performance of new buildings. If imposition of federal standards is deemed inappropriate, Congress could ask DOE to provide additional assistance to state and local governments on code development and training; and to builders on design and construction techniques. The vigorous promotion of Model Conservation Standards by the Northwest Power Planning Council (1989), combined with technical assistance to builders and code officials and financial incentives to builders from the Bonneville Power Administration, is leading to substantial improvements in efficiency of new homes in the region.

DOE's current budget for standards and guidelines is $700,000 a year. Additional funding would allow the Department to more vigorously promote and demonstrate the benefits of state adoption of DOE's energy-efficiency standards for new buildings. Funds could be used to develop analytical tools to assist architects and engineers in the design of buildings that comply with the standard, to test and evaluate the field performance of buildings that meet the standards, and to develop implementation packages for state and local governments.

REVIEW DOE'S STATE AND LOCAL ASSISTANCE PROGRAMS

The DOE conservation programs (State Energy Conservation Program, Energy Extension Service, Low-Income Weatherization Program, and Institutional Conservation Program) were all created ten or more years ago. During the past eight years, these programs were under continuing attack by the Administration, so few opportunities existed to update and improve these programs.

Now it is time to carefully review these programs and focus them on the issues and problems of the 1990s. Perhaps, Congress should ask the National Research Council to review existing programs, to assess state and local needs that can be met by DOE, and to suggest designs for new programs that DOE can manage during the coming decade.

CONCLUSIONS

Increased public awareness of, and interest in solving, environmental problems plus a new administration offer fresh opportunities to improve this nation's energy productivity. Congress has a rare and important opportunity to develop a somewhat larger, much more visible and sustained government role in energy efficiency. This role includes additional funds for research and development; greater technical assistance to, and cooperation with state and local governments, energy utilities, and manufacturers; and possibly additional energy-efficiency standards.

Vigorously implementing such programs will save billions of dollars for the nation's energy consumers, reduce emissions of greenhouse gases and other pollutants, reduce dependence on foreign oil, improve economic productivity, and enhance international competitiveness. Finally, improving energy efficiency adds diversity and flexibility to the nation's energy system, an insurance policy that is both inexpensive and valuable. As the Quaker Oats commercial says, "It's the right thing to do."

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Mrs. LLOYD. Thank you. I certainly appreciate your testimony.

Dr. Patten, it is your turn.

Mr. MORRISON. Before Dr. Patten starts, I wanted to point out that he is an example of technology transfer. He was at Pacific-Northwest Laboratories and is now with private industry. And I hope you took some good ideas with you.

Dr. PATTEN. I have been heavily involved with both of your constituencies in the past.

Mr. MORRISON. It's nice to have you here.

Mrs. LLOYD. He is well-represented.

STATEMENT OF DR. JAMES W. PATTEN, VICE PRESIDENT FOR RESEARCH, CUMMINS ENGINE CORPORATION

Dr. PATTEN. Thank you for inviting me to testify here today on the DOE LCUP programs. First, it would be appropriate for me to tell you a little bit about my background, both with Cummins and DOE to put the comments in persecutive because I am going to dig into the technology transfer issue in a little more detail.

I joined Cummings with the objective of transferring technology to the diesel engine business from other advanced high-technology industries.

I now have the materials engineering and manufacturing processes research responsibilities at Cummins and I'm also responsible for the outside funding, both government and industrially-funded research and development activities at Cummins.

Cummins is a diesel engine manufacturer. That is all we make, diesel engines, and their associated components. We are independent and we sell most of our product to companies that also manufacture their own engines. So we are in competition with the internal divisions of our customers.

Our product line is centered around the truck-size heavy diesel engines, although we do go up in horsepower from there.

We are responsible for about 55–60 percent of the heavy duty truck diesels in the United States. So, almost every major truck manufacturer that you see represented on the highway has our engines in it. We also make a little over 40 percent of the heavy duty turbo chargers in the world through our subsidiary, Holset, and the turbo chargers are the object of some of the nickel aluminide technology we will talk about today.

We are on the order of $3.5 billion in sales with about one-third of the sales going overseas. And we manufacture in many locations around the world. But most of our engineering is done in Columbus, Indiana. I led the original Cummins effort to license the nickel-aluminide technology from Oak Ridge. That was the first license of that technology and was a precedent-setting interaction between private industry and the National Laboratory.

I also serve as an industry adviser for DOE and National Science Foundation in several different groups. I have been aggressively involved in trying to accelerate technology transfer and to get some of these laboratory centers of excellence working more closely with industry.

And of course the ECUT materials program has been part of the effort. I was at Battelle Pacific Northwest, as Mr. Morrison mentioned, for about 13 years, where I had the original Hanford Plutonium weapons group. One of my other responsibilities there was lead laboratory function for DOE in the combustion program. So I have been mixed up with DOE for many years in many different ways.

I am a metallurgist and a physicist. I am currently led to the establishment of two new technology driven joint ventures with Japanese companies that are up and running and are quite healthy right now. So I think that background may be a little different from what you hear from many of your folks here.

I did testify to this Committee once before in 1986 around the ECUT program. Today, I have been asked to comment on the nickel-aluminide project, which is part of the Department of Energy's ECUT program, and to focus my attention on an experience with the transfer of technology in industry.

As a little bit of general background for the Committee's benefit, the nickel-aluminides form a family of metal alloys that have unique properties relative to other metal systems people have tried to develop. They have known about some of the unique properties of this system for a long time, and they have tried to develop the alloy system but they have been foiled by the brittleness of parts made strictly from nickel aluminide.

An Oak Ridge scientist discovered some techniques to make these nickel aluminides ductile. And so they have become, as a result of that work, viable engineering materials.

Cummins is interested in these materials for their potential for turbo charger applications and turbo chargers provide high-pressure air for the highly fuel-efficient diesels today.

We are also interested in valves and valve seats, piston rings and other components. Other industrial applications for these same materials include aircraft fasteners, gas turbine components, glow plug elements for the indirect injection, spark assisted or glow plug assisted passenger car diesels and high-temperature heat exchangers. So there is a wide range of applications for these materials.

I was provided with four specific questions today relating to technology transfer and I'm going to use those questions to structure my comments.

The first question was: In the case of nickel aluminides, it appears the government went well beyond just basic research in that the ECUT program funded the technology development which enabled industry to do applications development. How important do you consider this government role in technology development to the overall success of technology transfer?

The reduction to commercial application in new scientific findings requires a large number of research, engineering, development, and manufacturing technology tasks that all have to be carried out successfully. If one of those tasks falls short of its goals, then there never will be a product that makes it to the marketplace.

It is important to understand, at least in our business, that the research phase only represents about 5 percent of the total effort or the total expenditure required to get all the way from a concept to production. So that risk in the remaining scientific and engineering investment are still very high after you have that first indication of successful demonstration in the laboratory.

An independent U.S. industrial concern may have a great deal of difficulty in providing either the engineering resources, the people skills, and so forth, the facilities or the long-term investment required to keep the development process in motion over a long time frame.

In the U.S., we have a very sophisticated and productive research infrastructure in the National Labs and universities. We also have a very sophisticated and productive product development and mass production and marketing infrastructure in industry.

We don't have a technology development infrastructure that links those two capabilities. Our offshore competitors recognize the situation and have really capitalized on it. They have focused on technology developments using our research results and the results of our understanding of product development and mass production in marketing. And they have been pretty effective at that game.

The situation is just beginning to gain widespread recognition. For the past few years, those of us who have struggled with technology transfer have grappled with a whole variety of reasons that might be creating the technology transfer problem. We have been rather slow in recognizing that the problem in many cases has been that the technology just doesn't exist to transfer.

And here I am defining technology as information that actually enables designer/manufacturer of a product or a service and is targeted at a specific end use need—it includes research results, but it is a lot more than that.

Our research centers typically produce the research results and do a very good job of that, but very little implementing or enabling technology. And our industries are just not geared up to make that transition. We are geared up to take technology and produce products with it.

In the case of the nickel aluminides, the DOE ECUT management at Oak Ridge did go well beyond the generation of the basic research results. Really, through some very long discussions with their industrial partners.

And they had maintained funding and continuity of the critical scientific manpower to get the technology developed to the place where industry could actually do something with it.

In addition, however, the industry partners have been a lot more open, have committed their funds and their people, their internal strategic thinking and so forth to the effort.

We have, in fact, in this particular case approached the technology development program together, each from our own respective bases and as a result, they are developing the critical technology. Much of it has been developed and much of it is still being developed.

The industrial partners are bearing an increasing share of the effort and a new family of materials is moving rapidly towards commercialization.

I brought a picture today and I will walk it up to you as soon as my testimony is finished. It shows a nickel aluminide turbo charger that we received from a batch of castings last week. It is the first example of that kind of a part ever, really.

It has been about four years since we started the process. If everything works extremely well, we might thinkably make it to production late this year, which would be a laboratory concept, or first demonstration of a scientific finding to production—time of about five years, which must be some sort of a world record. It normally takes on the order of 10 years to commercialize a new conventional alloy of a stainless steel or something of that nature.

Clearly, however, industry by itself that is geared towards product development and applications just couldn't have taken Dr. Lou's initial findings and produced products.

That technology development phase has been absolutely critical and, really, to be successful, it should be led by the researchers, in this case, the Oak Ridge people, at the earliest stages, and led by the industrial partners in the later stages.

But it has to be a joint effort throughout the lifetime of the project.

I believe that the experience with nickel aluminides may well contain the key to U.S. competitiveness in both military and commercial technology-driven arenas. The message is really very simple.

We have neglected technology development and we do have to change this. Everyone's ideas are necessary and we must work together.

The second question is: The Department of Energy waived the patent rights for nickel aluminide to the operating contractor of Oak Ridge National Laboratory, Martin Marietta Energy Systems. This waiver permitted Energy Systems to negotiate licenses for the technology on terms that were acceptable to industry. Would you have undertaken this development program and made a significant corporate investment if the patent had not been waived to the operating contractor?

Really, I would rather that question was stated a little bit differently, so I took the liberty of answering it pretty freely:

The U.S. industry must deliver a good return to shareholders in order to remain viable. In general, therefore, research investments will not made in areas where no ownership or exclusive use of results is possible. Very often, this exclusive use is provided by secrecy within our own industry or within our own company rather than by patent protection.

However, in the case of work with the National Laboratories, results quickly become widely known. License arrangements with some marketplace advantage would, therefore, be absolutely necessary to attract industry.

In addition, industry was clearly aware that necessary technology did not exist and that active participation of the Oak Ridge staff would be required to develop this technology.

As a result, the license arrangements that would directly support development of critical enabling technology through cooperative work with key Oak Ridge staff were also necessary to attract industry.

What do you see as the barriers, question three, that prevent more effective technology transfer from government laboratories to industry?

The most serious barrier to effective transfer of research results from government laboratories to industries is that required technology has not been developed far enough for industry to make use of it.

That is, transferrable technology has not been developed. Recognition of the problem is often the first step to solution. So, progress should be more rapid in the future, particularly if a better balance is struck between research and technology efforts.

And I would definitely argue for that better balance piece. I am not arguing for more funding. That is something for your Committee to struggle with. But I think guidance as to the balance between research and technology development would certainly be worthwhile.

Precedents have now been set in the ECUT program with respect to license agreements, ownership of intellectual property and other issues that have previously been serious barriers to commercialization of research findings.

With continued support from DOE and the Congress, the pace of progress in the future will likely be set by the pace at which capable and energetic people can be informed of the successes to date.

And I would argue that some broadcasting of those successes and some requirement for a study of those successes should be part of your guidance to DOE.

Question four: Does this example of ECUT staying with the technology even after a license has been granted to provide continuity and stability in research suggest a model for other federal programs?

I believe the ECUT example with the development of the nickel aluminides is clearly a case for study for other federal programs. There are many opportunities for improvement. The legal arrangements could be streamlined. The use of industry advisory groups should be expanded. And clear technology development targets should be set early in each program and reviewed regularly as some examples.

Those involved in the nickel aluminide program recognize many of these opportunities and have taken advantage of them.

The new high-temperature super-conductivity pilot center at Oak Ridge seems to be particularly aggressive in this regard. With encouragement, I think other programs will follow.

Thank you very much.

[The prepared statement of Dr. Patten follows:]

Dr. James W. Patten

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Testimony to House Subcommittee on Energy Research and Development

February 28, 1989

Introduction

Thank you for inviting me to testifying today on the DOE ECUT programs. First let me tell you a little bit about who I am and my involvement with Cummins and DOE to put my comments in perspective.

I am Jim Patten. I've been with Cummins for seven years. I joined Cummins with the objective of transferring technology to the diesel engine business from other advanced technology industries. I now have the responsibility for materials engineering and the manufacturing processes research and development activities. I've also been asked to develop the Government funded R&D activities at Cummins, so today's discussion is particularly important to me.

Cummins

Cummins is essentially a single product company manufacturing heavy duty diesel engines and related system components. We're independent and sell much of our product to companies who also manufacture engines for their own use. Our product line is centered on the truck-sized heavy duty diesel engines in the 50 to 500 horsepower range, with a major product line also extending to 2000 horsepower.

We manufacture about 55 percent of the heavy duty diesel truck engines in North America. We also make over 40 percent of the heavy duty turbochargers in the world through our subsidiary, Holset. Our annual sales are about $3.5 billion, with about one-third of these sales going overseas. We manufacture in several domestic and overseas locations, but most engineering design is done in our U.S. headquarters in Columbus, Indiana.

Interaction With ORNL, DOE, and Technology Transfer

I have led the Cummins effort to license nickel aluminide technology from ORNL, and regularly serve as an industry advisor for several DOE and NSF groups who are aggressively attempting to accelerate technology transfer and work more closely with industry (including the ECUT Materials program).

Before joining Cummins I was with Batelle's Pacific Northwest Laboratories for about 13 years, where I managed the original Hanford Plutomium Weapons Group. One of my other responsibilities at Battelle was the lead laboratory function for the DOE Combustion Zone Durability Program, so I have been familiar with internal workings of the DOE for many years. My PhD work was in metallurgy and physics, and I have done graduate work in business. Cummins is currently heavily involved in two technology driven joint ventures with Japanese companies that my group has led, so that I feel well qualified to speak to you about technology development and transfer and specific DOE programs. This will be the second time that I have testified before this committee (the first was on March 6, 1986).

Nickel Aluminide (Ni_3Al) Project and Technology Transfer

I have been asked to comment today on Ni_3Al project in the Department of Energy ECUT program and to focus my attention on our experience with transfer of technology to industry. Four specific questions were provided, and I will use these questions to structure my comments.

Question 1: In the case of nickel aluminides, it appears that the Government role went beyond just basic research in that the ECUT Program funded the technology development which enabled industry to do applications development. How important do you consider this Government role in technology development to the overall success of technology transfer?

Response: Reduction to commercial application of a new scientific finding requires that a large number of research, engineering, development, and manufacturing technology tasks be carried out successfully and in a coordinated way. If any given task cannot be completed, no product will be delivered to the marketplace, so that risk remains high until most of these tasks are successfully completed. The research phase of this process usually occurs first, and often only consumes a very small part (perhaps less than 5%) of the total resources required to generate a new product. In other words, risk and remaining scientific and engineering investment are still very high even after the first laboratory feasibility demonstration of a new scientific finding. At this stage of development a product is still uncertain and, at best, years in the future. An independent U.S. industrial concern may have difficulty in providing the engineering resources and long term investment required to keep the development process in motion.

In the U.S. we have a very sophisticated and productive research infrastructure in the National Laboratories and Universities. We also have a very sophisticated and productive product development, mass production, and marketing infrastructure in industry. We do not have a national technology development infrastructure to link these resources. Off-shore competitors have recognized this situation as an opportunity, have created strong technology development efforts, borrow freely from our research, product development, mass production, and marketing findings, and are very effective.

This situation is just beginning to gain widespread recognition. The past few years have produced an intense effort to facilitate "technology transfer" from centers of research excellence to industry. Many of us who have been engaged in this process have been slow to realize that we are having difficulty because there is very little technology to transfer. Technology is information that enables the design or manufacture of a product or service, which in turn actively satisfies a need. Technology is based on sound research results, and includes them, but it is much more. Our research centers produce research results, but very little technology. Our industries are effective in product and application development, but less so in technology development. We have a missing technology link.

In the case of nickel aluminides, the DOE and ORNL did go well beyond generation of basic research results, and maintained funding and scientific manpower for technology development. In addition, industry has been much more open and pro-active with their information, engineering manpower, and funding. We have, in fact, approached the technology development problem together, from both research and product development traditional bases. As a result, critical technology has been and is being developed. The industrial partners are bearing an increasing share of the effort, and a new family of materials is moving rapidly toward commercialization. Clearly, however, industries geared towards application and product development could not have made any substantial use of the original research findings. The massive technology development task was absolutely required, and is still in progress. To be most successful, it should be lead by the researchers in the early stages and led by the industrial partners in the late stages, but it must be a joint effort thruout.

The experience with nickel aluminides may well contain the key to U.S. competitiveness, in both military and commercial technology driven arenas. The message is very simple. We have neglected technology development, and we must change this. Everyone's ideas are necessary, and we must work together.

Question 2: The Department of Energy waived the patent rights for nickel aluminide to the operating contractor of the Oak Ridge National Laboratory, Martin Marietta Energy Systems. This waiver permitted Energy Systems to negotiate licenses for the technology on terms that were acceptable to industry. Would you have undertaken this development program and made a significant corporate investment if the patent had not been waived to the operating contractor?

Response: U.S. industry must deliver a good return to shareholders in order to remain viable. In general, therefore, research investments will not be made in areas where no ownership or exclusive use of results is possible. Very often this exclusive use is provided by secrecy, rather than by patent protection. However, in the case of work with a national laboratory, results quickly become widely known. License arrangements with some marketplace advantage were, therefore, absolutely necessary to attract industry.

In addition, industry was clearly aware that necessary technology did not exist, and that active participation of Oak Ridge staff would be required to develop this technology. As a result, license arrangements that would directly support development of critical enabling technology thru cooperative work with key Oak Ridge staff were also necessary to attract industry.

Question 3: What do you see as the barriers that prevent more effective technology transfer from Government Laboratories to industry?

Response: The most serious barrier to effective transfer of research results from Government Laboratories to industry is that the required technology has not been developed far enough for industry to make use of it. That is, transferable technology has not been developed. Recognition of the problem is often the first step to solution, so progress should be more rapid in the future, particularly if a better balance is struck between research and technology efforts.

Precedents have now been set in the ECUT program with respect to license agreements, ownership of intellectual property and other issues that have previously been serious barriers to commercialization of research findings. With continued support from DOE and Congress, the pace of progress in the future will likely be set by the pace at which capable and energetic people can be informed of our successes.

Question 4: Does this example of ECUT staying with a technology even after a license has been granted to provide continuity and stability in research support suggest a model for other federal programs?

Response: The ECUT example with the development of nickel aluminides is clearly a case for study by other federal programs. There remain many opportunities for improvement. The legal arrangements can be streamlined, the use of industry advisory groups should be expanded, and clear technology development targets should be set early in each program and reviewed regularly, for example. Those involved in the nickel aluminide program have recognized many of these opportunities and are taking advantage of them. The new High Temperature Superconductivity Pilot Center at Oak Ridge seems to be particularly aggressive in this regard. With encouragement, other programs are sure to follow.

Mrs. LLOYD. Thank you, Dr. Patten.
Ms. Stone.

STATEMENT OF SUSAN C. STONE, COMMISSIONER, ILLINOIS COMMERCE COMMISSION, FOR THE NATIONAL ASSOCIATION OF REGULATORY UTILITY COMMISSIONERS

Ms. STONE. Thank you, Madam Chairman and other distinguished members of the Subcommittee, both present and absent. I appreciate your patience in sitting through this afternoon. I found it fascinating and I have learned a lot.

I am a Commissioner on the Illinois Commerce Commission. My name is Susan Stone and I am testifying today on behalf of NARUC, the National Association of Regulatory Utility Commissioners, which, as you probably know, is a quasi-governmental, nonprofit organization that is now celebrating its 100th birthday.

Its memberships are governmental agencies that handle the regulation of carriers and utilities in all 50 States and other related entities.

NARUC's chief objective is to serve the public interest by seeking to improve the quality and the effectiveness of regulation.

The purpose of my testimony today is to strongly urge adequate funding levels for energy conservation programs in the Department of Energy's budget for fiscal year 1990. And I would like also to make a special appeal for a small, but highly significant budget line, which Eric Hirst referred to, the least cost utility planning budget.

Those of us who regulate utilities at the state level have a vital interest in the federal government's funding of energy conservation programs. Basically, it is important to keep in mind that electric and gas utilities combined use more than half of the energy consumed in the United States. And it is certainly not cheap.

Federal programs have helped millions of consumers to minimize their utility bills and have spurred the development of many new energy savings technologies by industry.

In part, because of federal investments over the past 15 years, energy efficiency had become the fastest growing energy source in the United States, and the most economical.

From our perspective, when low-income citizens insulate their homes with the help of federal weatherization assistance programs, for instance, the resulting savings are reaped year after year, reducing the need for other assistance programs which are often very costly and are mere stop-gaps.

Well-designed conservation and load-management programs aimed at reducing energy use can and do provide permanent solutions to these targeted groups. And I know that this is of great concern to Congress.

Similarly, federally-funded research and development has enabled you as industry to develop numerous energy saving innovations which are cutting energy costs across the country by billions of dollars. And you have heard of some of those examples already this afternoon.

I am not going to repeat them except to say that in many instances the return has been a fantastic ratio. We have one example where the return was 7,000/1, which seems like a good bang for the federal buck.

Indeed, the energy saving investments our country has made since the Arab oil embargo 15 years ago are saving at least $130 billion a year in energy bills, and I heard a higher figure quoted earlier this afternoon.

But, despite the gains made in energy efficiency, many of which were the direct result of the stimulus of federal support, since 1980, as we have also heard from Congressman Wolpe earlier this afternoon, government research and development in renewable energy has dropped 80 percent from its peak; this slack has not been taken up by private industry.

And it is pretty disheartening to read, as I did last week, a prediction of Edison Electric Institute that:

Electricity demand will grow virtually in lock-step with GNP through the turn of this century.

Clearly, this calls for federal resources to change the course of this undesirable and unacceptable trend, which can only affect the international trade position of our country very negatively.

I don't know how many of you saw yesterday's New York Times, which had a headline saying:

"U.S. Progress in Energy Efficiency is Halting."

And it reported that for 1976 to '86 there was a 24 percent increase in energy efficiency in this country. And since 1986, it first leveled off and has been declining in the past year or two.

To me, it is essential and to NARUC it is essential that FY-90, the 1990 Conservation appropriations not be cut below the current bare-bone level. We would like to see substantial increases for the DOE conservation programs and the alternative budget coalition, of which NARUC is a member is recommending appropriations of $222 million for research and development and $250 million for State and Local programs in the coming year.

I would just like to note that I have been a Commissioner on the Illinois Commission for five years, and this is the fifth year that I and my colleagues have come to the Hill to plead for restoration and expansion of a meaningful conservation budget.

The Congress has been generous in light of the Administrative direction that accompanied the budget recommendations. But I think it is time now, and I think the situation has become so critical that we really need to be sure that we have a predictable, adequate budget that gives federal support where it is most needed.

Turning from the general conservation budget, I would like to talk particularly about one R&D program which, unfortunately, has suffered recently during the climate of austerity. It is called the Least Cost Utility Planning, or LCUP initiative.

This tiny line item in DOE's R&D budget leverages millions of dollars worth of other conservation expenditures by overcoming market barriers to investments in energy efficiency. And by literally teaching the regulators and those who work with them and the utilities as to how this can be accomplished.

Least Cost Planning is a regulatory tool whereby utilities are required to consider a broad array of resource options both on the demand and the supply side in both traditional supply side and renewable co-generation and another host of options. Because Least

Cost planning is premised on the regulation of utilities at the State level, State Commissions play a pivotal role in the federal program.

And under LCUP, a State Commission might require, for example, that a utility invest in high-efficiency lighting for its customers as a least cost substitute for building a new power plant.

This innovative approach to utility regulation has already resulted in dramatically increased conservation investments in such jurisdictions as Wisconsin, California, Maine, the Pacific-Northwest, and many others which I won't try to list.

Promising developments are beginning to take place in other States, including my own, as a result of some of these LCUP initiatives. Since its inception three years ago, DOE's modest LCUP program has played a central catalytic role in the evolution of least cost planning processes at the State level.

It has created a vibrant nationwide network for designing and implementing least cost strategies. And this has resulted in the leveraging of federal dollars with contributions from States, municipalities, utilities, laboratories, universities and a variety of other organizations.

I would like to talk just briefly about some of the products of the Department of Energy's first LCUP grant to NARUC.

We had a highly successful national conference on least cost planning less than a year ago in Aspen. And, quite remarkably, it exceeded our expectations and we had Commissioners and staff from 40 State Commissions. We never thought there would be that much interest.

The transfer of technologies is always important, but that conference not only transferred technologies, but was an opportunity to exchange ideas, to discuss concepts, to come to an understanding among people who had been skeptical, perhaps cynical, perhaps hostile. I'm not suggesting that everybody has become a true believer, but I am suggesting that the exchange of ideas as well as of technologies has been so positive and has moved things along very much more rapidly than I would have predicted when we began this activity.

There had been many other products of the grant that NARUC has received. There have been some very clearly written handbooks and these are being updated and revised.

There have been numbers of grants to individual states and to individual commissions. And there has been a lot of exploration of some of the knottier problems that we must resolve if least cost planning and demand side management is going to become a serious component in most utilities' planning processes.

We have to work and we are deeply into that. We have to work on resolving the way for utilities to have profit in not filling kilowatts or in not filling therms. It has to become profitable to use demand side strategies.

And this may require some changes in the regulatory process. As a representative of Illinois, I am well situated to comment on the potential advantages of least cost planning if it is done in the proper way.

In Illinois, we are still wrestling with the consequences of having built massive, multi-billion dollar baseload capacity and have the devious distinction of having more nuclear units than any other

State; although no one intended it to come out this way, for a variety of reasons, this has turned out to be most cost planning rather than least cost as a way to meet energy needs.

The Illinois Legislature recognized this because rate payers were protesting against the escalating rates that were the necessary result of all of this building. And three years ago, the Legislature mandated least-cost planning for Illinois' electric and gas utilities when it rewrote the Public Utility Act.

At the time, our Commission was ill-equipped to fulfill these requirements because we lacked sufficient understanding, knowledge. We lacked staff. And we lacked the analytical tools.

As a result of DOE's LCUP grants, the Illinois Commission is getting itself in a far stronger position today to fulfill its statutory mandate. And we are only one example. There are literally dozens of States that are picking up this approach, but they need help.

So do the utilities that they regulate. Many unmet needs still remain. And these can be addressed most readily in our State and most others through restoration of DOE's former least cost planning funding level.

Congress recognized that hardware alone does not deliver energy savings. And in order to bridge the gap, the least cost planning projects that have been approved have been helping to move the state of knowledge to a much higher plane.

This small line item budget represents less than 1 percent of the conservation R&D budget. And, yet, it may be, in our view, the single most important item in the entire energy budget and, indeed, in our national energy and environmental future.

Thus, we were extremely disappointed by last year's vote of the House Appropriations Interior Subcommittee to cut Least Cost appropriations from a mere $2 million in FY-88 to just $700,000 in FY-89. As a result of the conference, compromised the current level of $900,000, is woefully inadequate to meet the research and informational needs of this rapidly-evolving field. And it is evolving at an amazing pace.

Regulators and utilities need improved computer models and data collection systems as well as the crucial networking function and information transfer provided by the DOE program.

We, therefore, urge this Subcommittee to support the restoration of the funding for LCUP at the level at least of $2 million, which it received in 1988, and to recommend this action to their colleagues on the Appropriations Interior Subcommittee to ensure consistency in Congress on according LCUP a high priority.

This level of funding has been endorsed by major national energy conservation organizations such as the Energy Conservation Coalition and the American Council for an Energy Efficient Economy, among others.

Two dozen national organizations concerned with conservation are developing a list of priorities for DOE's conservation programs under the auspices of the Alternative Budget Coalition.

We hope that the Subcommittee will carefully consider our forthcoming recommendations, which will highlight those programs that we believe offer the greatest energy-saving potential.

In concluding, there are at least three urgent reasons, some of which have been alluded to earlier this afternoon, why serious and substantial funding for energy conservation and the LCUP programs in particular should be granted.

These concern environmental and economic considerations and resource preservation.

Mr. Ledbetter quoted from the National Academy of Sciences in their predictions on the effects on global warming, acid rain, local air pollution and energy security. Others have written similarly, and the warnings are dire.

The alternatives are present, and the question is:

Have we got the fortitude to choose the long-term right way? The cornerstone, as was said, by Project 88, a research project sponsored by Senators Wirth and Heinz:

"The cornerstone of any program to fight global warming is likely to be promotion of energy efficiency and non-fossil fuel energy generation; encouraging a more energy-efficient economy will mitigate the greenhouse effect and will reduce problems with local air pollution and acid rain."

As far as the economy is concerned, my second reason for doing this—if other reasons were not self-evident—as we look at our trade balance, we have to be reminded that the United States spends 11 percent of its GNP on energy supplies, while Japan spends only 6 percent.

I believe the question about comparative efficiencies was raised earlier this afternoon. If the United States were to match Japan's level, we would save $190 billion annually on energy bills with no loss in output of goods and services.

Think of the competitive advantage restoration that that might give us.

And, finally, as far as resource preservation is concerned, to the extent that we can extend the life of proven economically retrievable but unrenewable resources, we enhance our national security and we can avoid or postpone the need to explore for such resources in highly-sensitive areas.

Surely, these reasons are sufficiently compelling to justify a $2 million expenditure at this time to ensure the continued momentum of least cost utility planning and a sustainable energy future for our country.

I thank the Subcommittee for allowing NARUC to present its views on this vital subject.

[The prepared statement of Ms. Stone follows:]

BEFORE THE
UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH & DEVELOPMENT

TESTIMONY

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ILLINOIS COMMERCE COMMISSION

ON BEHALF OF THE

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ON

FUNDING FOR DEPARTMENT OF ENERGY CONSERVATION PROGRAMS FOR FY 1990

FEBRUARY 28, 1989

National Association of Regulatory Utility Commissioners

Testimony of Commissioner Susan C. Stone
Illinois Commerce Commission

"Energy Conservation -- A Winning National Investment"

Madam Chairman and other distinguished Members of the Subcommittee:

My name is Susan C. Stone. I am a Commissioner on the Illinois Commerce Commission. I am testifying today on behalf of the National Association of Regulatory Utility Commissioners (NARUC). NARUC is a quasi-governmental, non-profit organization founded in 1889. Within its membership are the governmental agencies of the fifty States, the District of Columbia, Puerto Rico and the Virgin Islands engaged in the regulation of carriers and utilities. NARUC's chief objective is to serve the public interest by seeking to improve the quality and effectiveness of regulation.

The purpose of NARUC's testimony is to strongly urge adequate funding levels for energy conservation programs in the Department of Energy's budget for fiscal year 1990.

Those of us who regulate utilities at the state level have a vital interest in the federal government's funding of energy conservation programs. These federal programs have helped millions of consumers to minimize their utility bills and have spurred the development of many new energy-saving technologies by U.S. industries. Due in part to the wise investments made by the federal government over the past 15 years, energy efficiency has become the fastest growing energy source in the U.S. economy, and the most economical.

It would be difficult to find a better place to invest federal funds than in energy conservation. When low-income citizens weatherstrip and insulate their homes with the help of the federal Weatherization Assistance Program (WAP), for instance, the resulting savings are repeated year after year, reducing the need for other assistance programs that are mere stopgaps and often almost literally equate with pouring money through a sieve because many of the poorest citizens live in the least energy efficient dwellings and use hand-me-down inefficient appliances. Well-designed conservation and load-management programs aimed at reducing energy use can and do provide permanent solutions to these target groups.

Similarly, federally funded research and development has enabled U.S. industries to develop numerous energy-saving innovations which are cutting energy costs across the country by billions of dollars. Let me offer just one example of the impressive track record of federal expenditures on energy conservation R&D: A $5-million expenditure of federal funds has resulted in the development of more efficient lighting and window technologies which are expected to save consumers $36 billion --a return of 7000 to 1. Indeed, the energy-saving investments our country has made since the Arab Oil Embargo 15 years ago are saving our country $130 billion a year in energy bills. Despite the gains made in energy efficiency, many of which were the direct result of the stimulus of Federal support, the fact is that since 1980, government research and development in renewable energy has dropped 80% from its peak. This slack has not been taken up by private industry. Most disheartening is the recent Edison Electric Institute prediction that electricity demand will grow virtually in lock-step with GNP through the turn of the century. Clearly, this calls for Federal resources to change the course of this undesirable and unacceptable trend which can affect the international trade position of this country very negatively.

It is essential that FY 1990 appropriations not be cut below the current bare-bones levels. Ideally, NARUC would like to see substantial increases in funding for DOE's energy conservation programs. The Alternative Budget Coalition, of which NARUC is a member, is recommending appropriations of $222 million for research and development and $250 million for state and local programs in FY 1990.

At this point, we would like to call the Subcommittee's attention to one particularly important R&D program which unfortunately has suffered recently during the climate of austerity in the Federal budget. It is called Least-Cost Utility Planning, or "LCUP." This tiny line item in DOE's R&D budget actually leverages millions of dollars worth of other conservation expenditures by overcoming market barriers to investments in energy efficiency.

Least-cost planning is a regulatory tool whereby utilities are required to consider a broad array of resource options. According to one definition, LCUP is:

> ...an integrated energy planning process that evaluates conservaton and improved energy efficiency equally with other traditional supply options and which explicitly recognizes and accounts for the external benefits and costs of energy conservation and improved efficiency by considering its environmental, economic, and societal impacts.

Because LCUP is premised on the regulation of utilities at the State level, State commissions play a pivotal role in the Federal LCUP program. Under LCUP, a State commission might require, for example, that a utility invest in high-efficiency lighting for its customers instead of building a new power plant.

This innovative approach to utility regulation has already resulted in dramatically increased conservation investments in jurisdictions like Wisconsin, California, Maine, and the Pacific Northwest. Promising LCUP developments are beginning to occur in dozens of other states as well, including Ohio, Pennsylvania, Rhode Island, and Illinois.

Since its inception three years ago, DOE's modest LCUP program has played a central catalytic role in the evolution of the least-cost planning process at the State level. With the help of Federal funding, utilities, regulators and local governments have teamed up with DOE's national laboratories to create a vibrant nationwide network for designing and implementing LCUP strategies. The small number of Federal dollars invested in this line item have been well leveraged with contributions from States, municipalities, utilities, laboratories, universities, and a variety of other consumer organizations.

Among the products of DOE's first LCUP grant to NARUC was a highly successful national conference on least-cost planning held in Aspen, Colorado last April and attended by representatives of 40 State commissions. Clearly written handbooks and technical papers produced through the LCUP program are widely used by regulatory agencies in developing energy conservation and least-cost planning programs at the State level. Grant monies have also been used to further the development of analytical tools and research on such issues as financial incentives for utilities to invest in conservation.

As a representative of Illinois, I am well situated to comment on the potential advantages of Least-Cost Planning, if done well, as opposed to the traditional approach. In Illinois, we are still wrestling with the consequences of having built massive multi-billion base load capacity, and have the dubious distinction of having more nuclear units than any other State. Although no one intended it, for a variety of reasons, this has turned out to be a most cost way of meeting energy needs. LCUP offers a strong and sensible alternative, by laying out all options--both supply and demand side--and considering renewables, cogeneration and IPPs with shorter lead times and reduced risk.

The Illinois Legislature mandated least-cost planning for Illinois' electric and gas utilities when it rewrote the Public Utility Act three years ago. At the time, the Commission was ill-equipped to fulfill these requirements because it lacked sufficient understanding, staff, and analytical tools. As a result of DOE's LCUP grants, the Illinois Commission is in a far stronger position today to fulfill its statutory mandate. However, many unmet needs still remain. These can be addressed most readily in our State and most others through restoration of DOE's former LCUP funding level.

In creating innovative programs like LCUP, Congress recognized that hardware alone does not deliver energy savings. The LCUP program ensures that energy-saving devices will not be left on the shelf simply because commissions, utilities and their customers lack the knowledge or financial incentives to make cost-effective efficiency improvements. Because it can lead to the delivery of energy-saving measures to millions of homes and businesses across the country, LCUP is an essential part of DOE's energy conservation R&D program.

As State utility regulators, we believe that this small line item, representing less than 1% of the conservation R&D budget, may be the single most important item in the entire energy budget and indeed in our national energy and environmental future. Thus, we were very disappointed by last year's vote by the House Appropriations Interior Subcommittee to cut LCUP appropriations from $2 million in FY 88 to just $700,000 in FY 89. The current compromise level of $900,000, approved in conference, is woefully inadequate to meet the research and informational needs of this rapidly evolving field. Regulators and utilities need improved computer models and data collection systems as well as the crucial networking function and information transfer provided by the DOE program.

We urge this Subcommittee to support the restoration of LCUP funding at least to the $2 million level this program received in FY 1988 and to recommend this action to their colleagues on the Appropriation's Interior Subcommittee to ensure consistency in Congress on according LCUP a high priority. This level of funding has been endorsed by major national energy conservation organizations such as the Energy Conservation Coalition (ECC) and the American Council for an Energy Efficient Economy (ACEEE).

Two dozen national organizations concerned with energy conservation are currently developing a list of priorities for DOE's conservation programs under the auspices of the Alternative Budget Coalition. We hope that the Subcommittee will carefully consider the Coalition's forthcoming recommendations, which will highlight those programs that we believe offer the the greatest energy-saving potential for the future.

There are at least three urgent reasons to provide serious and substantial funding to energy conservation and LCUP programs: environmental, economic, and resource preservation.

1) Environmental: the recently issued public policy study called, "Project 88", sponsored by Senators Wirth and Heinz, strongly recommended a set of policies to deal effectively with the combined problems of global warming, acid rain, local air pollution, and energy security, mainly--though not exclusively--by encouraging more efficient energy production and use of energy throughout the U.S. economy. They found that, "a comprehensive energy efficiency program will go a long way towards reducing some of our major environmental problems while providing society with a broad range of important economic benefits . . . The cornerstone of any program to fight global warming is likely to be promotion of energy efficiency and non-fossil fuel energy generation. Encouraging a more energy efficient economy will mitigate the greenhouse effect and will reduce problems with local air pollution and acid rain."

2) Economic: Insofar as economic benefits are concerned, not only must we reduce residential and business customers' energy bills but, by reducing energy bills for industry, monies are freed for use in plant modernization and expansion. It is of vital importance to our trade balance to change the current level of

industrial expenditures on energy. The U.S. spends 11% of its GNP on energy supplies while Japan spends only 6%. If the U.S. were to match Japan's level, we would save $190 billion annually on energy bills with no loss in output of goods and services.

3) Resource Preservation: Finally, to the extent that we can extend the life of proven, economically retrievable but unrenewable resources, we enhance our national security and can avoid or postpone the need to explore for these resources in sensitive areas.

Surely, these reasons are sufficiently compelling to justify a $2 million expenditure at this time to ensure the continued momentum of LCUP.

If a sustainable energy future is to be achieved, funding of efficiency and renewable energy research should be increased significantly. How we choose to produce and use energy in the immediate future and beyond, will deeply affect the quality and viability of our environment and our economy.

I would like to thank the Subcommittee for allowing NARUC to present its views on this vital subject.

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DOE LEAST-COST UTILITY PLANNING (LCUP) PROGRAM

Although cost-effective energy-saving opportunities abound in our country, such measures are adopted slowly and sparingly due to persistent institutional and market barriers. In addition to consumers' lack of information and their reluctance to incur the high first cost of some conservation measures, there is often reluctance by utility companies to encourage energy efficiency improvements which threaten to reduce sales of their product.

Regulation of utilities offers an opportunity to overcome these barriers through the adoption of innovative utility planning strategies. Utility regulators at the State level have developed a promising tool known as "least-cost utility planning," whereby utilities consider a broad array of energy resource options (including energy efficiency improvements) and choose the mix of options which offers the lowest long-term cost to consumers.

Experts predict the nation could reduce its energy bill by billions of dollars annually by incorporating cost-effective energy efficiency measures into utility planning. Moreover, least-cost utility planning can offer cost-effective solutions to environmental problems such as acid rain and global warming.

Through DOE's Least-Cost Utility Planning (LCUP) program, utilities, regulators and local governments have teamed up with DOE's national laboratories to create a vibrant nationwide network for designing and implementing LCUP strategies. The LCUP program helps to document least-cost planning successes in areas like the Northwest and Wisconsin so that they can be adapted to other jurisdictions.

Another priority of the LCUP program is the development of new least-cost planning tools for State regulators. These include analytical devices such as improved computer models for utility planning, as well as innovative regulatory strategies such as demand-side bidding and ratemaking incentives for utilities to pursue conservation.

Success stories, analytical tools and innovative regulatory strategies are shared through workshops, conferences, technical papers and an electronic communications network. In 1988, the LCUP program produced a least-cost planning handbook for utility regulators as well as a national conference on least-cost planning attended by regulatory officials from more than 40 States.

(over)

Despite the impressive accomplishments of DOE's LCUP program in its first two years, there remains a long list of priorities for future work on least-cost utility planning (see box below). Much work needs to be done on data collection, computer modeling and the development of utility financial incentives. Moreover, the national networking function facilitated by DOE will continue to play a vital role in this rapidly developing field.

Least-cost utility planning ensures that cost-effective energy efficiency measures will not be left on the shelf simply because utilities and their customers lack the knowledge or financial incentives to make cost-effective efficiency improvements. Because it can deliver energy-saving measures to millions of homes and businesses across the country, LCUP is an essential part of DOE's energy conservation R&D program.

DOE's LCUP program received only $900,000 in appropriations for FY 1989, a substantial reduction from the $2-million level it received in FY 1988. The Alternative Budget Coalition recommends that Congress restore LCUP funding to the $2 million level for FY 1990.

Priorities for Future LCUP Work

- Continue to stimulate successful implementation of least-cost utility planning at the State level
- Expand networking function which shares LCUP successes, analytical tools and innovative regulatory strategies among State utility regulators
- Develop a reliable data base documenting the performance and cost of various demand-side options which can be incorporated into utility planning
- Develop modeling software to simplify demand-side and integrated resource planning by utilities and regulators
- Develop regulatory alternatives which reward utilities for successful implementation of least-cost planning
- Develop means of incorporating environmental and other social costs into LCUP analysis

Prepared by:
Richard E. Morgan
D.C. Public Service Commission
February, 1989

PANEL 2 DISCUSSION

Mrs. **Lloyd**. Thank you very much, Ms. Stone. I would like to go back to your comments on our energy bill compared to the Japanese energy costs.

Are you saying that their cost of energy for manufacturing is half that of the United States

Ms. **Stone**. Yes. I'm saying, and I'm sure that Mr. Hirst can provide some more technical information to back this up, but I'm saying that to produce any unit of production, it costs less than half as much in Japan as it does in the United States because the energy bill costs less than half as much for the energy portion of production, which ultimately of course affects the price at which that product is sold.

Mrs. **Lloyd**. If I'm not mistaken, Japan has made a major nuclear commitment. Is that not true?

Ms. **Stone**. I think it is true.

Mrs. **Lloyd**. That would be one of the factors in their lower utility bill.

Ms. **Stone**. I think it is unquestionably true. I think it is partly a problem of the mix and how much reliance is placed on what sources. And no matter what you use, whether it is nuclear energy or something else, whether you sell less or more of it because your end uses are more efficient, I think is the key question.

In Illinois, for example, as I mentioned, we have 13 nuclear plants. That doesn't mean, however, that we can't promote, and require our utilities to promote, the rebate programs and other things that will encourage the use of highly-efficient appliances, whether it is air conditioning, refrigeration or whatever, as well as efficiency in building envelops and machinery and so forth.

I think, to the extent that in the future we can forestall having to build baseload plants that require huge capital investments, long lead times, massive uncertainty as to what the demand will be at the time that that plant is completed and in service, to the extent that we can avoid that, we reduce the risk for utilities for our national economy and for everybody concerned.

Mrs. **Lloyd**. I feel that we have received conflicting testimony over the past few weeks because last week we heard from proponents of nuclear energy that Japan is making massive investments in nuclear power, and this is one of the reasons why they are being able to move ahead of us in this area.

And then, today, it seems to me that the thrust of your testimony is that because we are making some of these commitments, that we are behind Japan.

I was confused with your testimony.

Ms. **Stone**. I'm sorry if that's the case, because I think that we are behind Japan in terms of competitive advantage insofar as they can manufacture a widget with less input of capital than we can. And to the extent that that energy component can be controlled, they have been controlling it and so have many western European nations, West Germany in particular, but others as well.

And I think that is what we need to be concerned about.

Now, Japan of course has no oil and depends on the import of 100 percent I believe of its oil. So, for them, maybe a nuclear component in their energy mix makes sense. And I would not be here to suggest that any one alternative is totally right or totally wrong. But I think what we are trying to do in this country at this time in the conservation budget and the least cost approach is to strike a balance and to make sure that whatever option we select, it is, in fact, the least cost.

That, if you choose a conservation measure, it is because it costs, for example, 2 cents per kilowatt hour to use that. But, if you choose a coal-fired plant, it could cost more than 2 cents per kilowatt hour, then that is not a least cost choice. And that would be a poor choice.

Mrs. **Lloyd**. I hope you understand the philosophy of this Member. Certainly, I think the record shows that we have been responsible for restoring money to the renewable program to the conservation program, and we hope to achieve a balanced energy mix. But, at the same time, conservation is not going to turn a single light on.

Ms. **Stone**. Well, there is already a great reservoir of power. And the question is:

Can you make that power do more work for you?

Mrs. **Lloyd**. It seems to me that we are sometimes comparing apples and oranges here.

Ms. **Stone**. I don't think that is necessarily the case. It seems to me that if you can get a 15-watt bulb to give the luminescence of a 75-watt bulb and the cost comes out to be cost-effective, that you have accomplished least cost planning. You have turned that light on and you haven't had perhaps to build that next new incremental plant.

Mrs. **Lloyd**. It is my position that we have to have both.

Ms. **Stone**. I think we do.

Mrs. **Lloyd**. There are large investments that have to go into a power plant. We can stretch out the kilowatt hour by having conservation.

Ms. **Stone**. Absolutely.

Mrs. **Lloyd**. But, first of all, you have to have the power plant and certainly that does cost more than conservation.

Ms. **Stone**. I think that is true and I think that what we are seeing is that we want to make sure that knowing what we have today, knowing what the life expectancy of some of these plants is and the obsolescence of others is, that we want to, in the future, not place sole reliance upon the traditional sources of supply, which have been baseload plants with major capital investments, that we want to see a mix. And we want through the development of reliable tools that can analyze and measure, we want to be sure that we are getting a least cost mix in the long-run, which also takes account of environmental impacts.

Mrs. **Lloyd**. Thank you very much.

Mr. Hirst, you mentioned that in educating America to the benefits of energy efficiency, we would need increased efforts by the government.

How do you recommend that we increase our efforts?

Mr. **Hirst**. The reason I put that in my testimony is I think we have gotten very conflicting signals from the federal government over the last eight years. Actually, ever since energy efficiency became an issue, which is way back in the Nixon Era.

I think the Nixon and Ford Administrations put some funding into energy efficiency, but it was not a priority for them.

President Carter considered it very important, but I think he inappropriately emphasized the deprivation aspects of conservation, sort of freezing in the dark, and did not appropriately emphasize the energy efficiency, the kinds of things that your Subcommittee has been funding—ways of doing more with less energy inputs.

So I think many people got the wrong impression of what we mean by energy conservation. In the past Administration for eight years they have been out and out hostile to any kind of a federal role in energy efficiency.

I think now with the new Administration and a growing awareness of the global environmental issues, particularly global warming, we have an opportunity to have a unified front from the Congress and the Administration that tells the American people what they already know, but emphasizes it—the benefits, the value, the importance of improving energy efficiency.

Mrs. LLOYD. Certainly, we need a sustained commitment as to the rollercoaster budgets that we have had through our R&D programs.

Mr. HIRST. I agree.

Mrs. LLOYD. But, looking at the overall programs, and this Committee is the steward of the Energy Research and Development dollars, and we're going to be looking at this very carefully this year.

How would you rank—let me ask you this also, Dr. Patten—how would you rank our energy efficiency technology development with regard to our overall energy activities? We do have a commitment to our power plants that are aging. We do need to upgrade our fossil plants.

We do need to continue with our nuclear research.

If you were sitting on this side, how would you plan to allocate these dollars?

Mr. HIRST. I guess I would allocate more to energy efficiency. Not because I think energy efficiency is the only energy resource. I agree with you. We have to have power plants. We're going to have to build more combustion turbines, coal plants and, eventually, nuclear plants or fusion.

The reason I would emphasize energy efficiency from the perspective of the federal government is that, in terms of the supply resources, there is an industry out there. There are the electric utilities, the gas utilities and the manufacturers. You've got Westinghouse, GE and others, and they can shoulder much of the burden for the R&D; whereas, on the efficiency side——

Mrs. LLOYD. I don't agree with you on that statement.

Mr. HIRST. I'm not surprised. [Laughter.]

On the efficiency side, there tends to be less of a strong central large manufacturing industry, particularly in the building area. The buildings area is dominated by lots of small manufacturers and thousands of architects and engineers, builders and developers. And they really cannot put together the R&D programs that the federal government can, and I believe should.

So, if I were in your shoes, I would shift some of the funding towards energy efficiency, but even more importantly I think is the need to increase the funding.

I don't want to be recommending that you rob Peter to pay Paul. I think, as Susan Stone mentioned, as Marc Ledbetter before us, Mr. Wolpe did before, the problems that energy efficiency can solve, the benefits that we can get from improving energy efficiency are so large that we ought to increase the funding.

Mrs. **Lloyd**. Thank you. Dr. Patten.

Dr. **Patten**. In the heavy duty diesel business, our customers are very aware of fuel consumption. That is the most significant piece pf their operating expenses that they can see. So the industrial side is very, very attuned in our business to more energy efficient propulsion systems.

We can still use a great deal of help from the scientific minds and the longer planning horizons that national laboratories have. That sort of conservation, that energy efficiency improvement, for the kinds of hardware that we are concerned with is absolutely crucial.

Sorting those out, sorting those factors out, is what will determine whether or not we remain a world leader in the diesel engine business.

It is true, however, that our planning and funding horizons are about five years out and we are restricted to something on the order of 5 percent of sales in R&D. So the impact that DOE can make on that business for ourselves and the other key actors comes really in terms of supporting the longer-range R&D kinds of activities that they are charged with supporting today.

I think it is very highly-leveraged work. It does reduce the consumption of petroleum rather substantially. The heavy duty transportation system is basically what keeps this country moving. We don't have a tremendously developed and aggressive, well-used rail or barging sort of maritime system. So most of the country operates off of heavy duty trucking.

I have heard so many pleas today for more funding and yet I come from a summer at Stanford listening to the economists argue about the national debt, the budget deficit issues, and so forth. And I guess I believe in having to live within one's budget.

So I think the questions are more proportioned where you spend the money, then just have you multiply ad infinitum.

It does seem to me that there are some areas that are less productive than others. And I'm not at all sure that the proportions are appropriate. But coming from a special interest group, the diesel engine industry, I'm not sure it is my position to argue as one more individual that you ought to fund——

Mrs. **Lloyd**. Good for you. We appreciate that. Thank you very much.

Mr. Morrison.

Mr. **Morrison**. Ms. Stone, happy 100th anniversary to your Association.

Ms. **Stone**. Thank you. I will pass that on.

Mr. **Morrison**. You have been in business for sometime and we congratulate you.

Ms. **Stone**. Some days I feel like I have been around the whole time.

Mr. **Morrison**. We are 100 years ahead of you, but I can't say that we can say that we've done any better.

Dr. Patten, I'm really very interested in the subject that you touched on and have some experience in that is really sort of the cutting edge of a lot of people we have listened to.

That is, your concept of our inability to get products from the laboratory bench, the technology, as we call it, through the developmental stage and into the marketplace. And that is what you have done in your shift from PNL to Cummins.

Would you comment a little bit more on that?

We have heard several ideas. In fact, one mentioned earlier today that maybe we need to have the government charge in and buy the first 100 models, or whatever, just to assure the manufacturer of the high cost of getting from the research point through the developmental stage.

But any other approaches that you can think of, or just comments generally in this area?

Dr. **Patten**. Yes. In the 20 or so years that I have been watching DOE go through its various phases of ERDA and AEC and the rest of it, I have seen a whole variety of different priority structures, all the way from demonstration plants to nothing but long-range high-risk research.

And it remains a fact that that technology development piece is absolutely required for commercialization of new concepts. And that the industrial sector isn't fully competent to do that piece of work.

We have just gone through an exercise for about the past four years of developing ceramic wear components for heavy duty diesel engines. And that is something I have watched after for that entire time.

We are amassing a bank of parts to go into production, full-scale production, today and it should happen late this month, or the first part of next month. That is work that could have been accelerated substantially with the national laboratory involvement.

But we really scouted around for interest in that sort of thing, couldn't find it. The interest was in high-temperature ceramics rather than such mundane things as wear-resistent components.

The U.S. ceramics industry didn't have the infrastructure to do that development work and we wound up with a joint venture with the Japanese helping. We are a worldwide company and we will do whatever is required to remain competitive worldwide.

But I have to tell you that I exercised every option to find a U.S. partner either in a national laboratory or in an industrial firm before I went overseas to establish that partnership.

We are successful now and I don't know whether we will wind up with a U.S. partner eventually, but there is another very clear example that, you know, I have lived through in the past few years.

Another one that is very similar is we had a very difficult powder metal fabrication task. We had a very real opportunity if we could get that problem solved. And it was a technology problem; it wasn't a fundamental science problem.

We were able to find in another Japanese firm the technology development infrastructure that could support that activity.

We formed a joint venture with the Japanese firm. We were able to move very, very quickly. A year after we started the discussions with the Japanese firm, we actually signed a joint venture. That was a year ago this past October.

Last month, we made a million parts.

It will be over a 40 percent ROI investment for us. That should have happened with a U.S. partner if there had been the technology development infrastructure. But, most of the folks in the PM area in the United States were either on the commercial side and didn't have the technology development infrastructure, or were on the research side either in a laboratory, in a national lab or a university and the principals had already been established.

So the answer was you couldn't get from point A to point B with our national resources.

So there are several examples like that that are very clear and are there to be studied.

Mr. MORRISON. Mr. Hirst, how do you react to this?

I almost get the feeling there is a wide gap between the two of you right there. In the scientific arena, you are working on a number of things that are exciting, tremendous potential. I know we have some advisory committees and that sort of thing.

Is there some way to fill that gap that you see so that you two can lock arms and lead America to a brilliant future?

Mr. HIRST. It would be nice if we could. I don't think that Dr. Patten and I differ really. I am not on the technology side of the conservation program at Oak Ridge. I don't know nearly as much about that area as I should.

But my impression is that, in the last few years, there has been a lot more attention paid ever since Martin Marietta took over Oak Ridge National Laboratory. There's been a lot more attention paid to technology transfer.

There is now a Vice President for Technology Applications. There is a whole office whose sole purpose is to find industrial partners that will work with the laboratory taking technologies from the laboratory through what you call the technology development process to commercialization.

My impression from talking with these people is that there remain a number of legal and regulatory hurdles.

And I think the bill that you have proposed last year, Madam Chairman, was designed to overcome some of these hurdles.

I have one very small example, trying to negotiate a contract between a laboratory and a private utility in your State, Puget Power. For me to work with them on the Least-Cost Planning Project, it was a very small contract and it took seven months of negotiations. No problems on the Puget Power site, lots of problems in the Department of Energy, Oak Ridge Operations Office in the Martin Marietta legal department.

DOE rules about indemnification, liability, patent rights, that really slowed things down. And I think my experience is not at all unusual. I think the typical case of industrial laboratory collaboration gets really slowed down and hampered by delays in procedures and legal issues associated with the contract.

Dr. PATTEN. That is true even with very missionary people. Both in the national laboratory and industry. And without the very missionary people, nothing happens at all.

The Oak Ridge folks have been absolutely precedent setters in this area. The ECUT program management have been precedent setters. They are clearly trying very hard to do a remarkable change in the thrust of their programs toward technology development.

But the direction that they have gotten from the Administration in the past has been:

Stay away from technology development. Do work that is very close to the research side. That research needs to be done but, a small amount of successful research will support a great deal of technology development.

Mr. MORRISON. I appreciate the comments of both of you on the subject. I think we are very proud of the progress that has been made. Part of it has come from legislative initiatives that have come out of this Subcommittee.

So we are encouraged by that. But I guess any time you give me sort of an opening like you have to say that there are still barriers out there, then I think we want to pursue them aggressively. And that fits precisely in today's subject of Conservation and Renewables and some of the more exotic research that we are doing; because if we are doing this research, making the investment, and somehow it doesn't get to the marketplace, we still haven't achieved, Madam Chairman, the goal that is essential for us and the responsibilities of this Subcommittee.

I thank all of you very much.

Mrs. LLOYD. Thank you, Mr. Morrison. We thank you.

We thank our witnesses. And I think the testimony has been excellent today. I thank you for the contribution you have made to our budget hearings.

If there is no further business—I would also like to thank the staff for their excellent work in preparing our hearings, our reporter.

And if there is no further business, the Committee stands adjourned until 1 o'clock tomorrow.

Mr. MORRISON. I had noticed in the testimony information from both Dow-Corning and Dupont, and I wonder if this could be made part of the record.

Mrs. LLOYD. Without objection, they will be part of the record of today's hearing.

If there is no further business, we stand adjourned until 1 o'clock tomorrow afternoon.

[Whereupon, at 4:42 p.m., the Subcommittee adjourned, to reconvene at 1 p.m., Wednesday, March 1, 1989.]

1990 DEPARTMENT OF ENERGY AUTHORIZATION

THURSDAY, MARCH 2, 1989

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Energy Research and Development,
Washington, DC.

The Subcommittee met at 1:35 p.m., pursuant to notice, in room 2325, Rayburn House Office Building, Hon. Marilyn Lloyd (Chairman of the Subcommittee) presiding.

Present: Representatives Lloyd, Morrison and Lamar Smith of Texas.

Also present: Robert S. Walker, ex officio.

OPENING STATEMENT OF HON. MARILYN LLOYD, CHAIRMAN, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Mrs. Lloyd. The Subcommittee will come to order.

Good afternoon, ladies and gentlemen. This afternoon marks the final in a series of our Subcommittee's authorization hearings on the Department of Energy's FY-1990 budget submission for civilian energy research and development. Our topic this afternoon is renewable energy and we have witnesses representing diverse technologies.

As we mentioned at our hearing on Tuesday, when Dr. Berg presented the FY-1990 request, the budget request for renewable energy and research and development is $109 million. This is a 26 percent decrease from FY-1989 appropriated levels. It is disappointing to again receive such a low funding request. To me it is a clear indication of how unimportant the Department considers this research effort.

I hope that during our budget deliberations we can restore funding to these important programs, at least to an adequate level to provide the programs with some stability.

Because of our extreme concern with the lack of emphasis on the renewable and conservation technologies within the Federal Government, Mr. Morrison and I introduced the Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989. We were joined as original co-sponsors by Representatives Sharp and Moorhead from the House Energy and Power Subcommittee.

As we begin our Congressional debate about striking a balance between energy and environmental concerns, I want to assure all of you that Mr. Morrison and I will take action on the bill as soon as our Subcommittee schedule permits.

Before I begin calling our witnesses to the witness table, I would like to again recognize my friend, Sid Morrison for any opening remarks he may have.

OPENING STATEMENT OF HON. SID MORRISON, RANKING REPUBLICAN, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Mr. **Morrison**. Thank you, Madam Chairman.

This has been, as always, a learning experience as we grind through the reviews of the budget process and one, by the way, on which I congratulate you on its structure. I think we have touched all the bases and got it done in an expeditious manner. My congratulations to you and the staff.

Mrs. **Lloyd**. And I thank you for your hard work as well as the staff's.

Mr. **Morrison**. I also would like to comment on the legislation that was introduced yesterday. Your leadership is very evident in that, and it does reflect I think the attitude of the Subcommittee and of the full Committee on just making sure we back up the renewable energy potential of this country, and I know we will hear today from a number of people with ways in which they would implement the expenditure of those funds.

So I look forward to hearing today's witnesses and I am pleased that we are nearing the end of a long march.

Mrs. **Lloyd**. But again we would like to remind the individuals that are interested in the activities of this Committee that just because we have sort of gone through the budgetary hearings in a hurry, we will be conducting oversight hearings throughout the year to give us more of an in-depth perspective of the issues that are before the Committee and also to review the progress during the year as well.

Our first panel of witnesses consists of Dr. Donald Klass, Executive Director of the Biomass Energy Research Association; Mr. David Rinebolt, Director of Research at the National Wood Energy Association; and Dr. David Block, Director of the Florida Solar Energy Center.

Gentlemen, please proceed.

Dr. Block, if you would like to go first.

Oh, Dr. Klass, would you rather go first? All right, that's fine with me, whatever.

PANEL 1

STATEMENT OF DR. DONALD L. KLASS, PRESIDENT, BIOMASS ENERGY RESEARCH ASSOCIATION

Dr. **Klass**. Thank you, Madam Chairman, for permitting me to go first, and Members of the Subcommittee.

First, I would like to point out that the Biomass Energy Research Association, or BERA, is a nonprofit association that was founded in 1982 by biofuels researchers and companies that are conducting biofuels research.

Our objectives are to promote education and research on renewable biomass and waste-to-energy systems that can be economically utilized by the public and to serve as a source of information on policies and programs for our members and industry.

We appreciate the opportunity again to present BERA's recommendations for the federal biomass and municipal waste R&D budget.

But before presenting BERA's position and recommendations on the fiscal 1990 budget, I would like to point out briefly that I have three sections in my statement, one on the unique features of biofuels, one on the present contribution to primary energy demand of biofuels and then a third section on the potential contribution to primary energy demand of biofuels.

I do not plan to review these for you, but I urge you to read them at your convenience.

Probably the most important piece of information presented in these three sections is the statement that biofuels currently contribute about three quad to U.S. primary energy demand and have the potential of contributing much more.

Now regarding global warming, there appears to be a national consensus among technical experts regarding the reality of the greenhouse effect. So I would like to make a few comments as to how the greenhouse effect relates to biofuels usage.

The greenhouse effect is caused primarily by atmospheric CO_2 buildup, and the role of biomass and biofuels in this environmental problem can help reduce the problem.

First, the ability of biomass to remove CO_2 from the atmosphere via biomass growth is one of the lowest cost methods of offsetting carbon emissions in the environment. And, as you may know, advanced biomass growth technologies are being researched and field tested that will capture four to five times as much CO_2 on an annual basis more than traditional forestry and agriculture.

About 1.2 billion acres of new biomass growth area is estimated to be needed to remove CO_2 from the atmosphere at a rate roughly equal to current global fossil fuel releases. This corresponds to a square area about 1,370 miles on each edge.

Unused potential cropland and setaside land totaling 225 million acres in the United States could be made available for new biomass growth.

And, finally, consumption of about 10 quad of biomass energy per year instead of coal would result in two trillion fewer pounds of CO_2 release and add no new CO_2 to the environment.

There is little doubt in our mind that the growth of biomass is the only practical way to remove CO_2 from the air, and that biomass derived fuels or biofuels are the only technologies that can remove both CO_2 and reduce the amount of fossil fuels burned.

Also, the fact remains that if the greenhouse effect is indeed real, the U.S.A. and other countries will inevitably be required to move toward non-fossil energy resources. Biomass growth and biofuels usage can play a major role in this endeavor now and in the future.

As pointed out last year in my testimony, the combined effect of a large budget reduction and a large amount of directed funding in some cases even for projects that have little or no relationship to biofuels had a strongly negative impact on biofuels R&D.

The directed funding levels for fiscal 1989 were over one-third of the already reduced appropriation of $13.4 million and resulted in major program reductions and terminations, such as almost all the ongoing conversion work on gasolines and diesel fuels.

After a detailed analysis of what occurred in fiscal 1989, I concluded that the primary benefit of continuing the biofuels program under these conditions is to maintain some of the key elements of the existing program and the expertise of a few of the scientists and engineers needed to mount a crash program in the future when fossil fuels are again in short supply. And, as I have pointed out before, a quality research program cannot be turned on and off like a light switch.

Examination of the biofuels budget proposed for fiscal 1990 by the Administration reveals even a more serious situation. The proposed budget is $9.1 million. This does not include the hydrogen research and development and the regional programs that were directed to be funded in fiscal 1989 at a total level of $4.4 million. If these programs are again directed to be funded without a corresponding budgetary increase, a balanced core biofuels R&D program will be impossible to maintain. Further major reductions and terminations will be necessary.

The most appropriate solution to this dilemma is to provide adequate funding for biofuels R&D and transfer the non-biofuels R&D on hydrogen to another office, such as the Office of Energy Research or the Office of Energy Storage and Distribution.

Now with regard to the fiscal 1990 biofuels R&D budget, the BERA Board of Directors has reviewed DOE's proposed fiscal 1990 biofuels R&D budget and the following recommendations represent our position on the R&D areas and the funding levels we urge you to include in next year's budget.

About one-half of our budgetary recommendation is again allocated to conversion because we believe that it is the foundation of a balanced program to develop advanced systems for the production of liquid and gaseous biofuels. We continue to believe the real potential of biofuels can never be realized without the development of efficient and economic conversion processes.

Also, I would like to emphasize that the industry co-funded medium Btu gasification demonstration plant that BERA has supported for several years is not mentioned in our recommendations. Five million dollars have already been separately appropriated for this scale-up program and will therefore not affect the R&D budget for fiscal 1990. BERA urges that the project be initiated before the end of calendar 1989.

I would now like to summarize BERA's biofuels recommendations for fiscal 1990.

In the area of biomass production, land and water base biomass grown and harvested specifically for biofuels represent a long-term approach to energy plantations that can supply large amounts of fossil fuel substitutes. Considerable progress has been made on efficient growth of biomass. We recommend that $5,400,000 be directed to continue this work.

Regarding thermochemical conversion research, this type of research to produce energy and liquid and gaseous fuels at competitive costs is the prime target of the program at the present time.

BERA's members feel that thermochemical conversion research on biomass and municipal solid waste should be funded equally. Municipal solid waste disposal is a nationwide problem that needs our immediate attention, while biomass offers a long-term approach to development of large-scale supplies of biofuels. We therefore recommend that $7,800,000 be directed to continue thermochemical conversion research on biomass and municipal solid waste.

In the area of biochemical conversion, application of the rapidly advancing field of biotechnology to the conversion of low-cost biomass to liquid and gaseous fuels, such as ethanol and methane-containing fuel gases, has made great progress and should be continued. We therefore recommend that $5,400,000 be directed to continue biochemical conversion research for liquid and gaseous biofuels production.

Now the regional programs established by Congress in 1983 make a concerted effort to transfer the technology resulting from the R&D programs to the private sector and are the link between the laboratory and commercialization.

The regional programs should be sustained because a transfer of the research results to technology users and the creation of a strong national biofuels industry are the ultimate goals of the biofuels R&D program. We urge therefore that funding be provided for the regional programs at a level of $3,100,000.

In summary, over the last few years a continually reduced appropriation has made it extremely difficult for DOE to sustain a balanced R&D program. A high proportion of a limited budget allocated to earmarked projects and expansion of the biofuels program to include non-biofuels research without corresponding budgetary additions caused major program reductions.

We strongly urge Congress therefore to appropriate a budget of $21.7 million as allocated above for fiscal 1990 and an additional $600,000 for capital equipment.

Finally, DOE's first multi-year plan for biofuels R&D was published in fiscal 1988. We recommend that the plan be updated periodically by DOE, particularly in view of the continued reductions in appropriations over the last few years. The program elements should also be related to the level of funding.

Thank you.

[The prepared statement of Dr. Klass follows:]

Statement of Dr. Donald L. Klass, President
Biomass Energy Research Association

Before the House Committee on Science, Space, and Technology
Subcommittee on Energy Research and Development

Hearing on Department of Energy FY90 Budget Appropriation
March 2, 1989

Thank you Madame Chairman and members of the Subcommittee. I am Donald Klass, President of BERA. BERA is a non-profit association that was founded in 1982 by biofuels researchers and companies that are conducting biofuels research. Our objectives are to promote education and research on renewable biomass- and waste-to-energy systems that can be economically utilized by the public, and to serve as a source of information on policies and programs for our members and industry.

We appreciate the opportunity again to present BERA's recommendations for the federal biomass and municipal waste R&D budget, and would like to commend the Subcommittee for its interest in and understanding of the role of biofuels in our national energy policy. Before presenting BERA's position and recommendations on the fiscal 1990 budget, I would briefly like to point out the unique features of biofuels, summarize their current contributions to energy demand, and indicate their potential.

Unique Features of Biofuels

- Biofuels are the only renewable resource capable of supplying substitutes for fossil-derived liquid, gaseous, and solid fuels, as well as heat and electricity, to all areas of the Nation and to all four sectors of the energy economy — residential, commercial, industrial, and transportation — from local resources.
- The widely dispersed nature of biomass and waste feedstocks for conversion to biofuels greatly improves our national security by providing a secure energy supply.
- Application of biofuels technologies to wastes offers opportunities for combined waste disposal-energy recovery-conservation systems.
- Biofuels are one of the most environmentally benign energy options and contribute little or nothing to acid rain, the Greenhouse Effect, or ozone layer destruction.
- Virtually all basic organic chemicals — including plastics and petroleum-derived products — can be manufactured from biomass and wastes thereby displacing and conserving depletable fossil feedstocks.
- Biofuels are the only renewable resource that can provide desperately needed local jobs and economic development in rural America.

Present Contribution of Biofuels

- In 1987, biofuels contributed about 3.0 quad of energy in all forms, or about 3.7% of our national total primary energy demand of about 80 quad.
- In barrels of oil equivalent per day (BOE/d), the contribution consisted of 1.3 million BOE/d from wood fuels; 52,000 BOE/d as heat, steam, and electricity from municipal solid wastes; 33,100 BOE/d as liquid alcohol fuels for vehicles; 18,900 BOE/d as heat, steam, and electricity from agricultural and industrial wastes; and 5,700 BOE/d as substitute natural gas from solid waste landfills and municipal sewage.
- At a price of $18 per barrel of oil equivalent, biofuels currently retain in the U.S.A. about $9.3 billion per year that are not expended on oil imports thereby having a strong beneficial impact on our massive trade deficit.
- Biofuels provide excellent regional benefits — 80 cents of every dollar spent on biofuels in a given region stays in that region, while 80 cents of every dollar spent on petroleum leaves the region.
- Utilization of biofuels supplies local jobs and income such as the 78,000 jobs and $1.9 billion in income in the Northeast that resulted from fuel wood usage in 1985, both of which have been projected to double by the year 2000.

Potential Contribution of Biofuels

- The theoretical maximum potential energy available each year from biomass and wastes about the turn of this century has been estimated to range up to 54.9 quad, or about one half of our projected energy consumption at that time.
- Municipal, industrial, and agricultural wastes are currently estimated to have an energy potential of about 15.0 quad per year, and wood and wood wastes are currently estimated to have an energy potential up to about 25.0 quad per year.
- Utilization of excess capacity croplands of up to 160 million acres projected beyond the year 2000 could produce up to 10.2 quad per year of energy crops. This could open the way to new food, feed, and fuel product flexibility to provide more stability to market prices, create new markets for the agricultural sector, and reduce federal farm subsidy payments.
- Under business-as-usual conditions, it has been estimated that total annual biofuels consumption at the turn of this century will be 4.8 quad, which is far less than the potential contribution.

BIOMASS AND BIOFUELS CAN HELP REDUCE GLOBAL WARMING

Since there appears to be a national consensus among technical experts regarding the reality of the Greenhouse Effect, which is caused primarily by atmospheric CO_2 buildup, a few pertinent comments are in order to illustrate how biomass and biofuels can help reduce this buildup.

- The ability of biomass to remove CO_2 from the atmosphere via photosynthesis and biomass growth is one of the lowest cost methods of offsetting carbon emissions in the environment.
- Advanced biomass growth technologies are being researched and field tested that will capture 4 to 5 times as much CO_2 on an annual basis than traditional forestry and agriculture.
- About 1.2 billion acres of new biomass growth area is estimated to be needed to remove CO_2 from the atmosphere at a rate roughly equal to current global fossil fuel releases. This corresponds to a square area about 1,370 miles on each edge.
- Unused potential cropland and set-aside land totalling 225 million acres could be made available in the U.S.A. alone for new biomass growth.
- Consumption of 10 quad of biomass energy per year instead of coal would result in 2 trillion fewer pounds of CO_2 release and add no new CO_2 to the environment.

There is little doubt that the growth of biomass is the only practical way to remove CO_2 from the air, and that biomass-derived fuels or biofuels are the only technologies that can both remove CO_2 and reduce the amount of fossil fuels burned. Also, the fact remains that if the Greenhouse Effect is indeed real, the U.S.A., which uses about one-fourth of the energy consumed throughout the world despite the fact that the U.S. population is only about one-twentieth that of the world, and other countries will inevitably be required to move toward non-fossil energy resources.

THE ADVERSE IMPACT OF DIRECTED FUNDING WITHOUT ADDITIONS TO BUDGET

As pointed out last year in my testimony, the combined effect of a large budget reduction and a large amount of directed funding, in some cases even for projects that have little or no relationship to biofuels, had a strongly negative impact on biofuels R&D. The directed funding levels for fiscal 1989 were over 1/3 of the already-reduced appropriation of $13.4 million and resulted in major program reductions and terminations, such as almost all the ongoing conversion work on gasolines and diesel fuels. After a detailed analysis of what occurred in fiscal 1989, I concluded that the primary benefit of continuing the biofuels program under these conditions is to maintain some of the key elements of the existing program and the expertise of a few of the scientists and engineers needed to mount a crash program in the future when fossil fuels are again in short supply. And as I have pointed out before, a quality research program cannot be turned on and off like a light switch.

Examination of the biofuels budget proposed for fiscal 1990 by the Administration reveals even a more serious situation. The proposed budget is $9.1 million; this does not include the hydrogen R&D and the regional programs that were directed to be funded in fiscal 1989 at a total level of $4.4 million. If these programs are again directed to be funded without a corresponding budgetary increase, a balanced core biofuels R&D program will be impossible to maintain. Further major reductions and terminations will be necessary.

The most appropriate solution to this dilemma is to provide adequate funding for biofuels R&D and transfer the non-biofuels R&D on hydrogen to another office such as the Office of Energy Research or Office of Energy Storage and Distribution.

BERA RECOMMENDS $22.3 MILLION FOR FISCAL 1990 BIOFUELS R&D
A Balanced Program of Production, Conversion, and Technology Transfer

The BERA Board of Directors has reviewed DOE's proposed fiscal 1990 biofuels R&D budget, and the following recommendations represent our position on the R&D areas and the funding levels we urge you to include in next year's budget. About one half of our budgetary recommendation is again allocated to conversion because we believe that it is the foundation of a balanced program to develop advanced systems for the production of liquid and gaseous biofuels. We continue to believe the real potential of biofuels can never be realized without the development of efficient and economic conversion processes.

Also, I would like to emphasize that the industry-cofunded medium-Btu gasification demonstration plant that BERA has supported for several years is not mentioned in our recommendations. Five million dollars have already been separately appropriated for this scale-up program and will therefore not affect the R&D budget for fiscal 1990. BERA urges that the project be initiated before the end of calendar 1989.

I would now like to summarize BERA's biofuels recommendations for fiscal 1990.

Biomass Production

Land- and/or water-based biomass grown and harvested specifically for biofuels represent a long-term approach to energy plantations that can supply large amounts of fossil fuel substitutes. Considerable progress has been made on efficient short-rotation intensive-culture tree production methods, and on the growth of aquatic species in low-grade saline water for liquid fuels and chemicals or in municipal waste-water as a low-cost, combined wastewater clean-up and biomass production system. In addition, research on tissue culture techniques and the application of genetic engineering methods to low-cost energy crop production, and the evaluation of herbaceous plants as sources of biofuels nationwide have shown promise. This work should be continued as an integral part of the biofuels program.

BERA recommends that $5,400,000 be directed to continue biomass production research.

Thermochemical Conversion Research

Thermochemical conversion research to produce energy and liquid and gaseous fuels at competitive costs is the prime target of this program component. Laboratory- and pilot-scale research on municipal solid wastes and biomass has established the technical feasibility of several advanced combustion, gasification, and liquefaction processes, and basic research is in progress to improve our understanding of the mechanisms of conversion and the formation of pollutants, especially from municipal solid waste-energy recovery facilities.

Direct liquefaction of municipal solid wastes, wood, and herbaceous feedstocks via production of biocrude and its subsequent upgrading by advanced catalytic processes to gasoline and diesel fuels show promise. Continued research is expected to increase the overall liquid yields to the point where the gasoline costs are competitive with those of petroleum-based gasolines. Thermochemical liquefaction of wastes and low-grade biomass for the production of low-cost fuel ethanol also shows promise and merits investigation.

Continued research on the thermochemical gasification of wastes and biomass has resulted in the development of advanced process designs and reactor configurations that maximize yields and provide optimum product distributions. For example, selected operating conditions can produce medium-Btu gas or optimum synthesis gases for manufacture of ammonia, methanol, methane, gasoline, or diesel fuels. This work has been performed at the laboratory and pilot scales and is ready for demonstration. Some research is still needed to perfect the feeding of diverse biomass and waste feedstocks at elevated pressures, the elimination of tars and particulates from product gas streams, and the recycling of residuals.

In combustion research, a need still exists for improved solid waste incinerators that meet environmental requirements and cost goals. Research should be focused on systems that can be used for economic disposal of municipal solid wastes in small communities.

BERA's members feel that thermochemical conversion research on biomass and municipal solid waste should be funded equally. Municipal solid waste disposal is a nationwide problem that needs our immediate attention, while biomass offers a long-term approach to development of large-scale supplies of biofuels.

BERA recommends that $7,800,000 be directed to continue thermochemical conversion research on biomass and municipal solid wastes.

Biochemical Conversion

Application of the rapidly advancing field of biotechnology to the conversion of low-cost biomass to liquid and gaseous fuels such as ethanol and methane-containing fuel gases has made great progress and should be continued. Process evaluations by experts have identified key opportunities for economic pay-backs with biochemical conversion systems, and new genetic engineering and other emerging biological approaches have made significant advances. Research needs have also been identified that should be addressed to increase our understanding of the biochemical and microbial interactions that occur in fermentation processes.

At this time, the cost of ethanol from biomass is approaching that from corn, and with continued research, we are confident the cost can be made competitive with fuels at today's prices without tax exemptions, thereby lessening our dependence on foreign supplies of petroleum while stabilizing .

fuel prices. Furthermore, the technical advances made through this program will benefit the competitive position of the United States in biotechnology world markets. Future research should be concentrated on conversion of low-cost feedstocks such as lignocellulosic wood wastes by high-yield acid- and enzyme-catalyzed hydrolysis processes, on development of innovative fermentation product separation schemes that have the capability of producing low-cost fuels and by-products, on the development of organisms that can metabolize the hemicellulose components in the feedstocks, and on the utilization of the lignin fractions as octane enhancers and chemicals.

Biochemical conversion systems are unique in that they can directly produce methane, the major component of natural gas, from the full range of low-cost biomass. Additional research is required to identify and develop organisms that increase both methane yields and gas production rates. Research is also needed to develop novel fermentor designs that permit higher feedstock concentrations and smaller reactor volumes, and therefore lower capital costs. This research is expected to lead to practical methods for producing substitute natural gas from low-cost biomass. And in the case of feedstocks such as municipal wastewaters, low-cost integrated biomass production-waste stabilization-methane production systems are expected to evolve from continued research.

BERA recommends that $5,400,000 be directed to continue biochemical conversion research for liquid and gaseous biofuels production.

Regional Programs

The Regional Programs established by Congress in 1983 make a concerted effort to transfer the technology resulting from the R&D programs to the private sector and are the link between the laboratory and commercialization. The Regional Programs should be sustained because the transfer of the research results to technology users and the creation of a strong national biofuels industry are the ultimate goals of the biofuels R&D program.

BERA urges that funding be provided for the Regional Programs at $3,100,000.

Recommended Budget

Over the last few years, a continually reduced appropriation has made it extremely difficult for DOE to sustain a balanced R&D program. A high proportion of a limited budget allocated to earmarked projects and expansion of the biofuels program to include non-biofuels research without corresponding budgetary additions caused major program reductions. BERA strongly urges Congress, therefore, to appropriate a budget of $21.7 million as allocated above for fiscal 1990, and an additional $0.6 million for capital equipment.

Program Evaluation

DOE's first multiyear plan for biofuels R&D has now been published. BERA recommends that the plan be updated periodically by DOE, particularly in view of the continued reduction in appropriations over the last few years. The program elements should also be related to the level of funding.

Mrs. LLOYD. Thank you, Dr. Klass.
Mr. Rinebolt.

STATEMENT OF DAVID C. RINEBOLT, DIRECTOR OF RESEARCH, NATIONAL WOOD ENERGY ASSOCIATION

Mr. RINEBOLT. Madam Chairman and Representative Morrison, thank you. We appreciate the opportunity to address the Subcommittee regarding biofuels R&D.

Dr. Klass and I work in much the same area, although Dr. Klass represents the research community and the National Wood Energy Association represents the manufacturers who produce the equipment and who manage the wood lots, the foresters and the harvesters who actually put wood energy products in the ground.

I think that these are the people who we have to thank primarily for the increase in the utilization of wood energy that we have seen throughout this decade. Prior to 1980, by our best estimates, there were approximately 250 megawatts of grid connected biomass power on line in this country. At the current time we estimate that the megawatts on the grid is around 5,100.

As you can see, that is a rather sizeable increase and it has been achieved without really too much federal support. The federal R&D budget under discussion today primarily revolves around developing liquid and gaseous fuels from biofuels and the technologies of conversion that are important to those processes.

None of the current research budget, with the exception of the regional programs, is allocated to the direct combustion industry, which produces about 95 percent of the power from biofuels in this country today.

I should also note that electricity production is really a small component of the amount of energy produced by biofuels. Only about 300 facilities in this country actually produce electricity. The remaining 2,700 approximately facilities in this country that use biofuels as their feedstock produce primarily steam and thermal loads.

A number of these facilities actually burn their waste products. A number of environmental groups have been concerned about increasing the use of wood energy, but we find through our membership that the vast use is of wood that exists as a waste product, as a by-product from manufacturing operations, or it is actually wood that is separated out from the municipal solid waste stream.

I cite in my testimony the example of the Islip garbage barge, which we are all fairly familiar with. That garbage barge did not include any wood in it. The wood actually was separated out and a member of our Association, member company, Hubbard Sand and Gravel, actually takes all the wood waste that is produced in the Islip area of Long Island. That wood is then chipped and sold to the Procter and Gamble Plant on Staton Island which produces 50 megawatts of electricity.

Hubbard Sand and Gravel and their President, Mark Kennedy is actually here today with us. It has laid the foundation for a three megawatt cogeneration facility which will be burning the wood wastes that they collect separated out from the municipal waste stream and produce three megawatts of power as well as processed steam for other energy demands in the area.

LILCO is happy to buy that power because it's more cost effective than the power from the Shoreham Nuclear Power Plant. So it's a win-win situation for everyone involved.

Since the oil prices dropped in the middle of this decade, most of the new construction of biomass facilities has been oriented towards reducing waste problems in Kentucky, for instance, and in Mr. Morrison's State of Washington as well as in the Chairman's State. A number of saw mills produce wood waste, sawdust, and traditionally that was landfilled or left to lie in a valley nearby where it leached into the groundwater releasing organics into the groundwater, and under RCRA and a number of other federal groundwater pollution control statutes the saw mills have been prevented from landfilling this residue.

The question is what are they going to do with it if they are not going to go out of business and stop producing it. The real answer that we found is to cogenerate or to use that waste produce to fire their drying machinery, the kiln dryers or to fire the steam needs of the facility to move the wood through the mills, and this has the double advantage of saving the company's money as well as eliminating their waste products.

So wood energy and biofuels energy in general has the opportunity to get you a twofer in a sense. Obviously, as Dr. Klass indicated, using biofuels for energy has a positive impact on the environmental situation that we are facing in regards to both the greenhouse effect and acid rain situation. Wood and biofuel agricultural residues, which are primary feedstocks, contain little or no acids and little or no heavy metals. So since they are not present in the feedstock, they can't be released into the atmosphere and cause us additional problems.

We also show the promise, and a large amount of work that is being done at Oak Ridge National Labs falls into this category. Using short rotation intensive crops for future biofuels production in the area of gasoline also offers us the promise to fix large amounts of carbon and cycle it out of the atmosphere where it has been released by fossil fuel combustion.

In addition, if you look at biofuels as a fuel cycle, you can only release into the atmosphere what carbon has been fixed within the feedstock during its growth period because woody fuels and other biomass fuels are grown over relatively short periods of time, and the growth at this period is exceeding the actual consumption of these feedstocks. You can actually draw the conclusion that the use of biomass is pulling carbon dioxide out of the atmosphere currently, and with an expansion of utilization shows the promise to continue that.

I should also like to mention the issue of economic development, and this is one that Dr. Klass did not touch on. But biofuels facilities and biomass facilities in general are located in rural areas. Calculations by the Meridian Corporation indicate that about $7.5 billion in capital has been spent on biofuels production or biofuels utilization facilities in the last eight years. Much of this capital has been spent in rural areas and, moreover, the harvesting of the feedstock and the processing of the feedstock obviously occurs in these rural areas as well.

In addition, we are currently working with the Agriculture Committee to look at the possibilities of using short rotation crops and short rotation forestry on conservation setaside lands. There we would have the double benefits of stabilizing endangered soils because the growth canopy from short rotation forestry really sets after the first year, and you can hold moisture in those soils and prevent the further erosion of the top soil in these highly erodible areas.

Regarding the specific budget, Dr. Klass and I diverge very, very slightly on our requests. The one program that the industry in this country feels very strongly about is the regional biomass energy programs. Those programs fund a series of regional efforts to promote the utilization of existing resources. They also transfer the technology that is developed in the national labs and, in addition, they provide a focal point for developers within those States for issues such as permitting for air regulations.

They have the decided advantage as well of attracting a large amount of matching funds both from industry and from the State governments. Several years ago I had the fortune to run the Northeast Regional Biomass Program, which at that time was funded to the tune of about $600,000 by the Federal Government. However, by the time we added up the matching from other Federal agencies, State agencies and the private sector, our program exceeded $1.5 million. So we were really in a situation where we were getting better than a dollar for dollar, leveraging more than a dollar from the Federal investment.

I think you find that this leverage holds true throughout those regional programs. They provide technical assistance within every State in this country, to saw mill operators who want to use their waste products, to environmental activists who are concerned about wood stove pollution and have run a series of workshops on wood stoves showing consumers and salesmen how to work the stoves better and how to make them perform better and thereby lowering emissions.

We are in a sense never going to be a technology or never going to be a fuel resource that we were a hundred years ago when we provided the vast majority of power in this country. But, nevertheless, wood energy provides an opportunity as a niche fuel in this country, and I think quite simply with only modest investments by the Federal Government, and even lower than those we saw during the first half of this decade, we could quite easily double the amount of energy produced by biofuels in this country over the next 10 years, and that is using existing technologies.

But, moreover, the existing industry and growth of the direct combustion industry provides the infrastructure that will be necessary to bring the technologies that SERI and that Oak Ridge are developing into the marketplace. You can't develop gasoline from wood unless you have a wood supply infrastructure, and that is what the existing industry has developed for us in this country today.

So I ask the support of the Subcommittee in pursuing the research agenda and in aiding us in providing the funding that we need for these programs to help the use of biomass energy increase in this country.

Thank you.

[The prepared statement of Mr. Rinebolt follows:]

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TESTIMONY

by

David C. Rinebolt
Director of Research
National Wood Energy Association

before

House Science, Space and Technology Committee
Subcommittee on Energy Research and Development

March 2, 1989
Washington, D.C.

"Wood Energy"
The Renewable Alternative

INTRODUCTION

Madame Chairman, I would like to thank you and the Subcommittee for providing the National Wood Energy Association (NWEA) with the opportunity to testify regarding the U.S. Department of Energy's biofuels research and development budget for FY 1990.

Between 1981 and 1987 spending by the federal government for biofuels research averaged $31.41 million dollars. During that time, biomass expanded its contribution to the nation's energy supply from 2.5 Quads to 3.8 Quads. This equates to an expansion from 3% to almost 5% of the country's primary energy supply. During the same time frame, electrical generation from biofuels in the form of small power producers, independent power producers and cogenerators, has expanded from an estimated 250 MW to 5,100 MW.

The credit for this expansion should go to the companies who make up the membership of the National Wood Energy Association - the project developers, equipment manaufacturers, architect and engineering firms, woodlot owners, and foresters who put the projects in the ground and develop and manage the feedstocks that fuel these plants.

The federal government also played a role in fostering the expansion of this underutilized energy resource. Tax credits, which expired in 1986 permitted, a commercial tax credit of 10% of the installed cost of these facilities. The Public Utilities Regulatory Policies Act of 1978 (PURPA) provided the regulatory framework necessary to allow small power producers and cogenerators access to utility markets. And, a sizeable research budget, averaging around $40 million during the first half of this decade, provided the research base necessary to increase the use of wood and other biomass fuels for energy.

In the last several years things have changed. The tax credits are gone. PURPA, thanks to a new series of FERC proposals, is in disarray because FERC recommends disregarding the original intent of PURPA to foster the use of renewables. And, the research budget has sunk to a minimal $13.435 million.

One should not get the impression, however, that the use of biomass energy is dependent on government involvement. This is not an industry that has depended on federally financed demonstration projects. The federal action early in the decades did help get the industry off the ground, but the federal investment has always been modest and, I think you will agree, has paid off rather handsomely as evidenced by the level of federal effort (see chart below) versus the amount of energy that has been generated.

As this nation considers the future, my membership believes that biofuels offers an economically and environmentally sensible solution to the need for additional electrical generation capacity, thermal and steam loads, gas supplies and transportation fuels.

ENVIRONMENTAL AND ECONOMIC CONCERNS

Acid Rain - Biomass offers a low cost solution to the problem of acid deposition. The reason is fairly simple; wood contains virtually no sulphur. So, whether you burn the wood or agricultural waste directly, gasify it, or convert it into ethanol, methanol or gasoline, it still releases no sulphur dioxide into the environment. Moreover, the limited research on cofiring wood with coal indicates that wood ash actually traps acids that would otherwise be emitted from the stack. One researcher has gone so far as to calculate that cofiring wood with coal can eliminate the need for scrubbers in some applications. The bottom line is that cofiring offers a low cost solution to the acid rain problem.

The Greenhouse Effect - Policymakers have recently begun to focus on the increasing concentrations of 'greenhouse gases' in the atmosphere. There seems to be little scientific doubt that increasing quantities of carbon dioxide, methane, chloroflourocarbons (CFCs) and other gases trap solar heat within the atmosphere and will result in eventual global warming.

While the combustion of biomass in solid, liquid or gaseous forms, does release carbon dioxide, when one looks at the use of biomass as a cycle which includes the growth of trees or crops there is no net increase in atmospheric carbon levels. This concept is known as the carbon cycle. As trees or other biomass materials grow, they absorb carbon from the atmosphere; the more rapid the growth, the greater the carbon absorption. Carbon is fixed in the plant until it is harvested. Once harvesting takes place, the carbon is inevitably released regardless of whether the biomass is burned or naturally deteriorates. So long as you are regrowing sufficient biomass to replace what you harvest, there is no net increase in carbon dioxide released to the atmosphere. If you are 'mining' the resource, as is occurring in South America, the cycle is thrown out of balance. In the United States, we are in a reforestation situation - we are growing more trees than we are harvesting - so our present use of our biomass resources actually is helping to solve the problem.

Much of the biomass used for energy in this country is waste wood that would otherwise rot in the forest or be hauled to a landfill. The decomposition of biomass produces an acid run off and methane - both harmful to the environment. Methane is four times more efficient at blocking infrared radiation as carbon and as such is one of the strongest contributors to the greenhouse effect. Burning the biomass for energy eliminates the methane release.

In addition, a number of researchers, many of them funded by the biofuels budget under discussion today, are looking at short rotation forestry (SRIC) as a means of removing carbon from the atmosphere. SRIC forestry involves using hybrid trees which grow rapidly, fixing large amounts of carbon from the atmosphere. For instance, work on hybrid poplar being done at Oak Ridge National Laboratory has produced trees growing on a plantation site in Oregon that reach a trunk diameter of 6 inches in five years and are fifty feet high. Moreover once the trees are harvested they regenerate themselves through a technique called coppicing - in other words, they grow back from the trunk that remains. The harvested trees can be used to substitute for fossil fuels in boilers, or converted to pipeline quality gas, chemical feedstocks or even gasoline. The Department of Energy has calculated that the production of of methanol or gasoline from wood with regrowth would actually decrease the amount of carbon in the atmosphere. (See attachments.)

Solid Waste - We are all aware of the waste disposal crisis that is facing this country. Perhaps you remember the garbage barge that went on a world cruise. Well, that barge carried trash from Islip, New York. The trash did not include any wood. Why? Because one of our member companies, Hubbard Sand and Gravel, accepts all of Islip's clean wood waste (tree trimmings, pallets, packages, construction debris, etc.) and processes it into wood fuel which is burned in a 50 MW power plant owned by Proctor and Gamble on Staten Island. Hubbard is also in the process of building its own 3 MW cogeneration station that will provide electricity for 2,000 homes and steam to heat a series of greenhouses to be built on the site. The diversion of that wood extends the life of the existing landfills, and eliminates a potential cause of groundwater pollution. It also minimizes the chance that methane, produced during the decomposition of the wood in the landfill, can migrate into nearby homes creating a potentially explosive situation. Overall, segregated wood -waste now comprises approximately 25 percent of the volume of our nation's landfills, so the resource potential is quite extensive.

Economic Development - Wood power plants are generally located in rural areas and are labor intensive due to the harvesting and handling requirements of the facilities. As many of you know, rural areas are the most difficult places in which to foster economic growth. The growth of the biomass energy industry has resulted in the expenditure of approximately $7.5 billion of investment capital in the last eight years, much of it in rural areas. Increased utilization of our biomass resources will require that more capital flow into rural areas resulting in additional employment.

BIOFUELS ENERGY SYSTEMS BUDGET

The last seven years have seen continuous reductions in in the R & D budgets for both biofuels specifically, and renewable energy in general. The cuts have in renewables have been far greater than other U.S. Department of Energy research programs:

PROGRAM	FY'81	FY'89	PROPOSED FY'90
BIOFUELS	$57.7	$13.4	$ 9.0
TOTAL RENEWABLES	$557.1	$80.03	$67.7

The Subcommittee should realize that current mid- and long-term R & D efforts within the Biomass and Municipal Waste Technology Division (BMWT) of the Department of Energy are currently at rock bottom levels. The Subcommittee should further realize that these research programs, while necessary to the future energy security of the country because they will provide alternative liquid and gaseous fuels for use in the transportation sector, have limited relevance to the commercial wood energy industry which is based on direct combustion technology. The only programs within BMWT which provide direct assistance to the industry are the Regional Biomass Energy Programs, now operating nationwide. These are zeroed out in the President's request, as they have been since their inception in 1983.

Recent funding for Biofuels Energy Systems has been constantly declining:

Program Activity	FY'88 Actual	FY'89 Appropriation	FY'90 Request	FY'90 NWEA Proposed
Terrestrial Crops................	$3,383	$3,800	$3,800	$4,250
Aquatic Energy Crops................	1,490	1,100	1,100	200
Thermochemical Conversion...........	3,345	3,755*	1,400	4,475
Biochemical Conversion...........	4,390	2,130	2,100	5,695
Regional Program.......	4,000	2,000	0	5,400
Capitol Equipment......	600	550	600	600
NWEA New Initiatives..........	0	-0	0	1,500
Total, Biofuels Energy Systems	$17,055	$13,435	$ 9,000	$22,000

* Includes $2.4 million for hydrogen research.

NWEA contends that a reversal of this decline is warranted. We believe it is counterproductive to continue to maintain or in some cases increase funding for fossil and nuclear R & D while ignoring indigenous renewable energy resources. Frankly, when one combines the effects of the new tax law, which continues to grant tax advantages to fossil and nuclear while denying any advantages to biomass, and the heavily one-sided R & D budgets, which subsidize commercial technologies, renewable technologies are at a decided disadvantage. We therefore recommend, at a minimum, a funding level of $22,000,000 for Biofuels Energy Systems. In addition, R & D work within SERI and Oak Ridge National Laboratory must be maintained and potential R & D which highlights new environmentally benign products or processes should be encouraged.

NWEA has also strongly objected to funding hydrogen research out of the biofuels budget. In FY 1990, US/DOE has recommended a discrete line item for hydrogen since it can be produced through the use of all renewable technologies. NWEA urges the Subcommittee to support a line item for hydrogen research.

NWEA believes that the U.S. biofuels program must be more responsive to the direct combustion industry. At least $1 million of directives out of the overall budget must be included. NWEA recommends that the following research initiatives as part of that directive

WOOD ASH DISPOSAL - States and the U.S. EPA are becoming increasingly concerned and aware of potential contaminants in ash. While the ash resulting from buring raw wood chips, forest residues and other uncontaminated wood is actually beneficial as a soil additive, urban wood waste such as demolition debris can contain contaminants. Research in this area, performed in conjunction with U.S. EPA can prevent restrictive regulations from prohibiting the utilization of this resource.------$250,000

COMBUSTION OF 'UNCLEAN' WOOD - Several states have banned the burning of fiberboard, particleboard and flakeboard, among other wood products, because of a fear that the binders used in these materials have the potential to produce air toxics. While manufacturers have indicated that no toxic precursors are used in the binders, states require documentary evidence. Unfortunately, wood systems using these wastes as fuels are generally used and manufactured by small to mid-sized companies who cannot afford the testing. The manufacturers of these products do not view these composite boards as fuels, so testing seems pointless to them. However, some federal seed money spent in cooperation with industry, would allow the test burning of these materials and the determination of which ones can be cleanly burned and which should not be. Burning of these materials, when appropriate, eliminates the necessity for landfilling of these wastes, an obvious advantage.------$200,000

WOOD/COAL COFIRING - Additional research into the dynamics of wood/coal combustion could help provide answers to the Department's attempt to find ways of burning high sulphur coal cleanly. Evidence exists that indicates that cofiring with wood does have an impact on the formation of sulphur dioxide. Research could be done at facilities currently cofiring these two fuels.------$150,000

WOODFUEL STORAGE AND DELIVERY SYSTEMS - Additional work is needed in the development of economical woodfuel storage and delivery systems. In particular, work is needed on leachates from stored wood fuel, handling systems for large sized woodfuel, and small scale chip delivery systems, to name just a few potential topics. Research in these particular three areas would answer questions about potential groundwater contamination, help decrease the amount of energy utilized in processing woodfuel, and aid in the development of new markets for wood energy systems, respectively.--------$200,000

WOOD ENERGY STATISTICAL INFORMATION - The information base of the federal government on woodfuel utilization is in a deplorable state. The last detailed federal information on the energy contributions of renewable energy was published in 1981. Policy makers such as this committee need information on a feedstock providing five percent of this nations energy if responsible decisions on energy issues are to be made. The Energy Information Administration has to capability to collect this information, but does not have the funds. Funding for this information is desperately needed.------$200,000

NWEA also recommends an additional $3,400,000 (for a total of $5.4 million) in funding for US/DOE's regional programs. These programs provide a conduit for the research conducted in the other BMWT programs, effectively moving this information out to the commercial industry. These programs also develop information essential to the industry such as resource assessments, providing technical assistance to potential converters to woodfuel, studying the impacts on the forest resource base of harvesting wood for energy, and helping to understand the environmental impacts of biomass utilization.

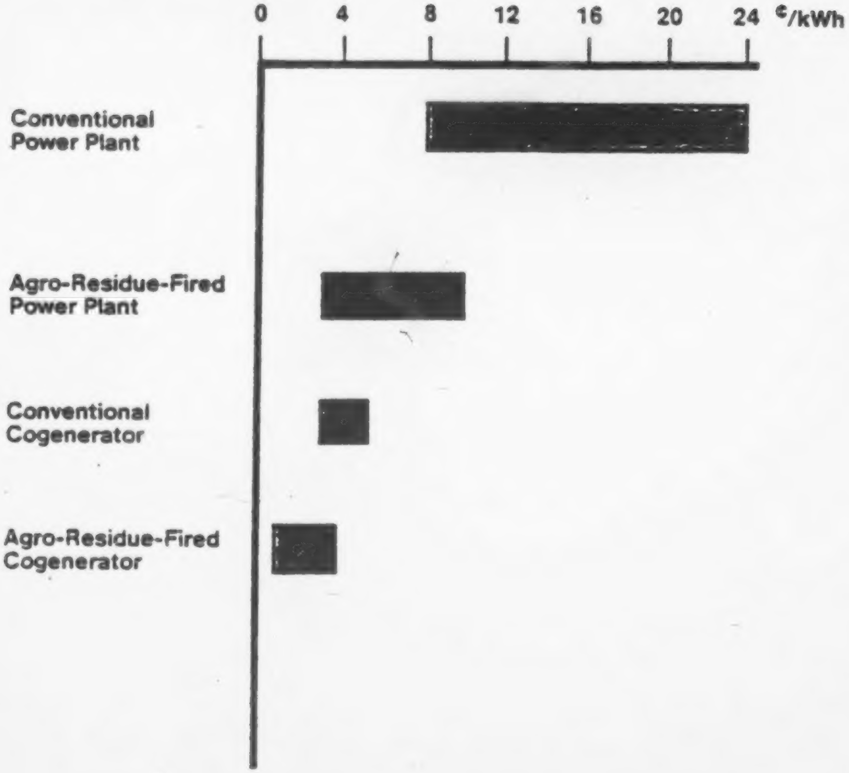
The Regional Programs have also worked in the agricultural sector to develop small scale biomass applications to help keep family farms viable, as well as developing networks of urban wood waste suppliers to provide low-cost or no-cost woodfuel, while helping to minimize necessary landfilling. The network of state officials involved in these programs prevents duplication of effort by government and enhances the ability of states to work with and understand an important energy resource. This increase is justified by cut in funding which occurred for the first time last year. The existence of a dollar for dollar match throughout the life of this program program warrants additional funding.

CONCLUSION

Constant decreases in federal R & D funding have not prevented the increasing use of wood for energy in this country. These decreases have, however, crippled the effort to develop alternative transportation fuels, which are vitally needed. Modest increases in funding can begin to recapture the momentum of the beginning of this decade, building on a leaner, tougher research base. Our international competitors are increasing their biomass programs in anticipation of a retrenchment in U.S. federal biofuels R & D. We must give our industry the research base with which to compete effectively in the international marketplace.

In addition, these modest requests can help break down the remaining barriers to the complete utilization of traditional direct combustion technologies: providing this country with increased energy independence; expanding job opportunities in rural areas; unleashing the environmental benefits associated with better managed woodlands; and, providing the satisfaction and economic consequences associated with spending American dollars for American fuels. Thank you.

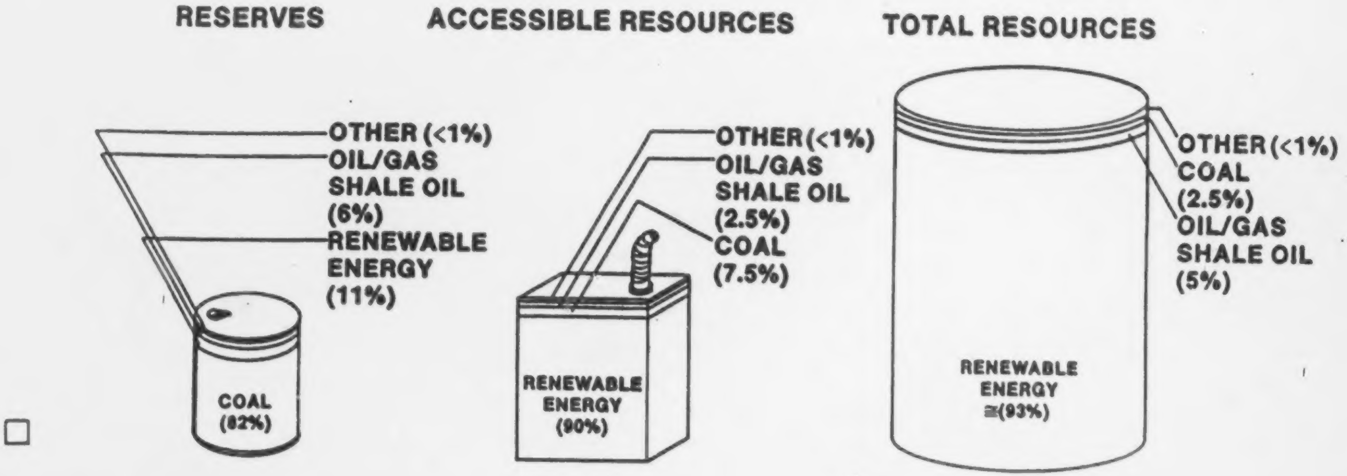
Total Capital and Operating Cost of On-Site Electricity Generation



Assumptions:

1. Plant size: 250 kW to 40 MW
2. Capital costs: U.S. $1,000-3,000/kW
3. No cost for feedstock.

U.S. ENERGY RESOURCE/ ESTIMATES

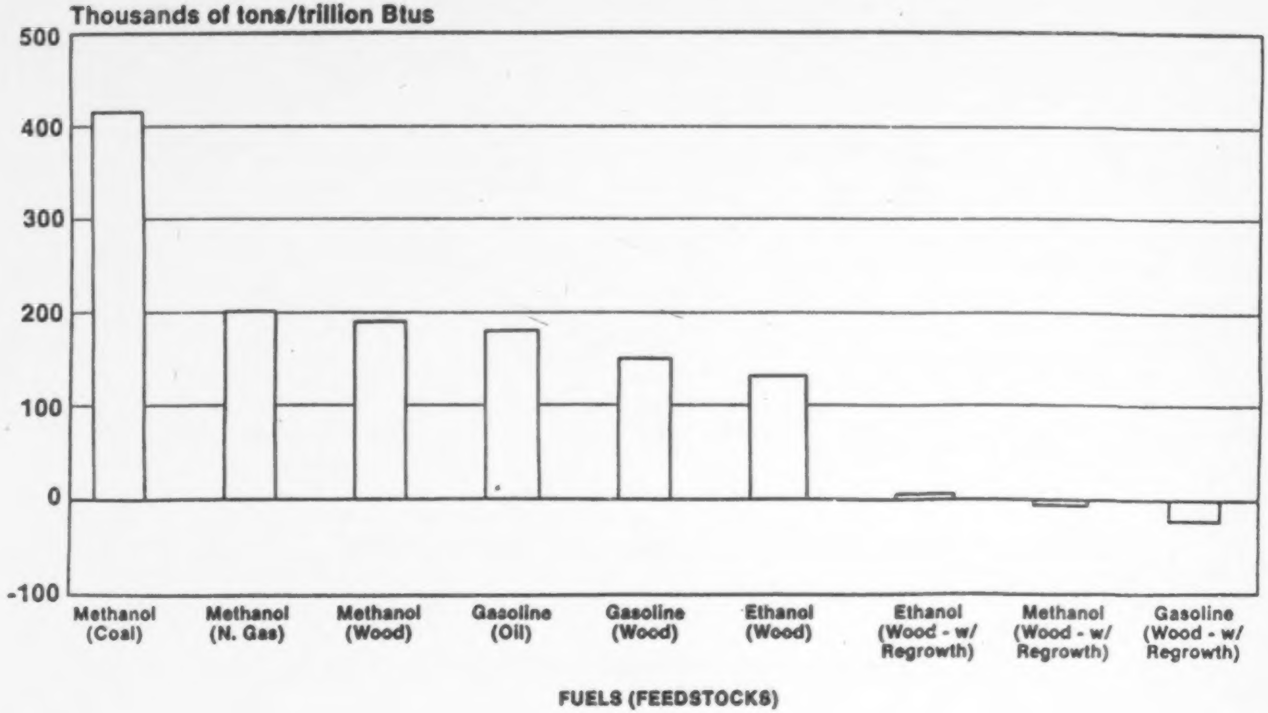


1,105 Billion Barrels of Oil Equivalent
(6,497 Quads)

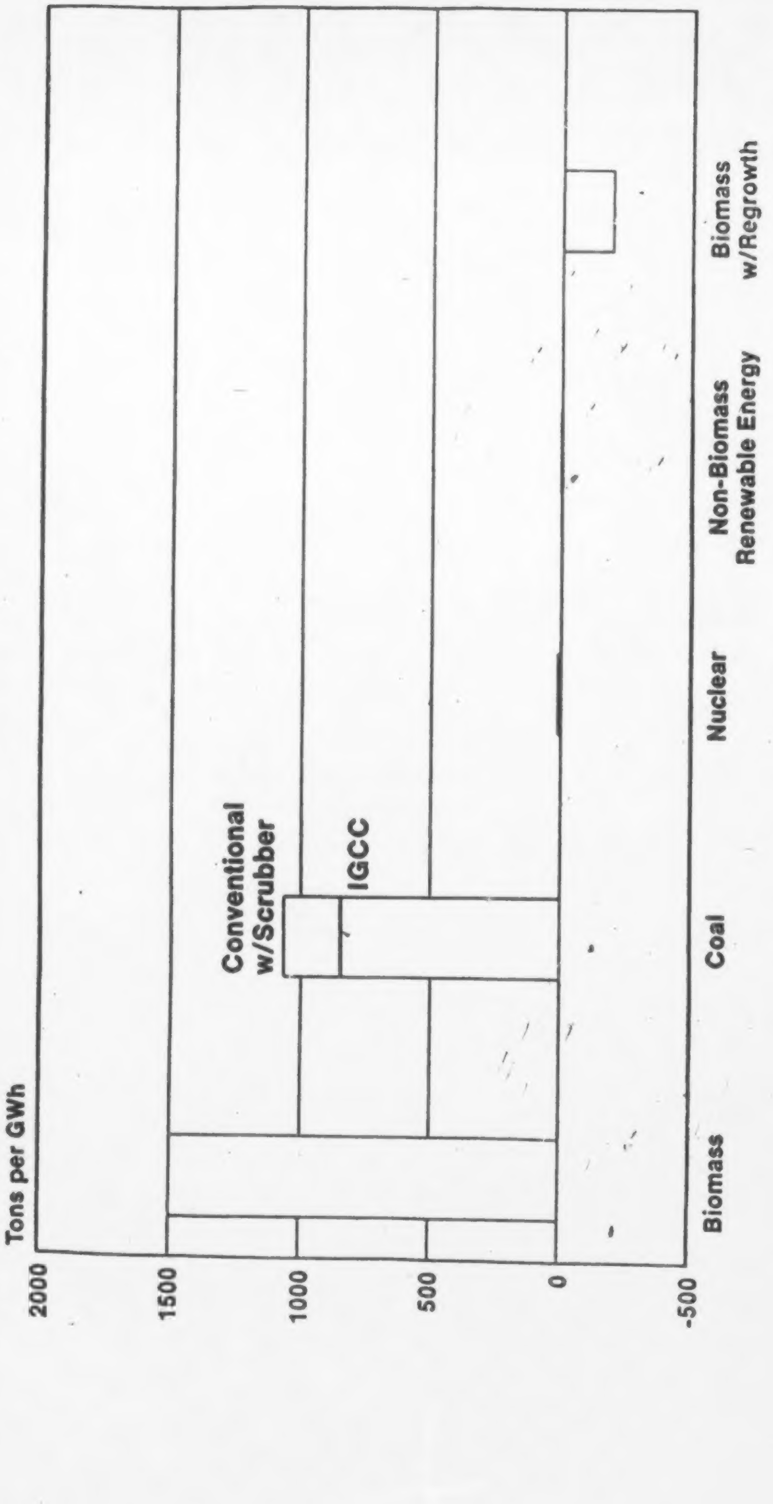
87,274 Billion Barrels of Oil Equivalent
(513,376 Quads)

599,322 Billion Barrels of Oil Equivalent
(3,525,542 Quads)

CARBON DIOXIDE EMISSIONS: LIQUID FUELS



CARBON DIOXIDE EMISSIONS: ELECTRIC GENERATION



WOOD ENERGY

AMERICA'S RENEWABLE RESOURCE

Until the 19th century, direct combustion of wood was the world's primary energy source. U.S. wood energy consumption reached its highest point in 1880 at 2.8 quads per year, and it's lowest consumption by 1960 at 0.8 quads. The energy crises in the 1970's reversed the decline in residential wood energy and continued the strong gains in the industrial sector.

The direct combustion of wood now rivals hydroelectric and nuclear power in energy produced. Over the past decade, wood energy consumption in the United States has increased in all four sectors: commercial, industrial, residential, and utility.

APPLICATIONS

In the U.S., 65 percent of the wood used for energy is for commercial, industrial and utility applications. The remaining 35 percent is used to heat 5.6 million homes entirely and 21 million homes partially.

During the 1970's, a dramatic growth in wood energy use occurred as high-priced oil was displaced for predominantly industrial and residential thermal applications. By the end of the 1970's, there were over 3000 commercial, institutional, industrial, and utility combusters in the United States with wood as the primary fuel source.

During the 1980's, an equally dramatic growth has occurred as electricity is being produced from wood thus offsetting high price electricity from nuclear plant overruns or oil fired plants. Several hundred wood and biomass power production plants are coming on-line in the mid-1980's with over 1000 MW of wood energy in California alone.

Other uses for wood energy are expanding as well. Wood gasification is being used in agriculture, industry, and commerce. Wood liquifaction into methanol, an alcohol fuel which can be blended with gasoline or used in its pure form, serves as an important transportation fuel of the future. Even a 10 percent market penetration of methanol fuels would displace one million barrels of petroleum per day at current consumption levels.

The United States leads in biomass usage worldwide and is reducing U.S. reliance on electricity and petroleum imports as exemplified by this wood power plant in California.

Wood energy has a vast potential in the United States, Canada, and throughout the world. According to the World Bank, the less developed countries of Asia derive 50-65 percent of their energy from wood or biomas (vegetable matter or organic wastes) while wood and biomass comprise from 70-90 percent of the energy resources of the lesser developed countries of Africa. Use of the more efficient technologies through U.S. exports will have substantial positive impact on these economies.

MARKETS

The major markets in the United States that have contributed to the development of the wood energy industry are the lumber and pulp & paper sectors in the 1960's and 1970's; the residential and non-forest sectors in the 1970's; and the utility sectors in the 1980's.

More effective resource management could increase available energy from forest, mill, agricultural and urban wood residues by 8-10 quads.

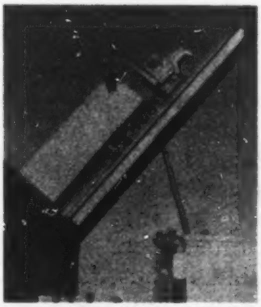
Pulp & Paper - In the 1980's the U.S. pulp & paper industry remains the largest consumer of wood fuel in the industrial sector. Almost 50 percent of all wood fuel is consumed by this industry, and wood supplies approximately 70 percent of this industry's energy needs. There exists a strong correlation between wood consumption and the output of the pulp & paper industry.

Lumber - The U.S. lumber industry has been the second largest consumer of wood fuel in the industrial sector in the 1980's, using almost 20 percent of wood fuel primarily for thermal applications.

Non-Forest Industries - Nearly 10 percent of the nation's wood fuels goes to the non-forest products industry which amounted to 51 trillion Btu's of wood consumed in the early 1980's. In some instances electrical energy was produced from biomass resources and sold to local utilities on a cogeneration basis.

Utilities - Some utilities burned wood for electricity in the U.S. between 1980-1983 with the largest facility generating 56 MW. Over 200 utility-interconnected plants (PURPA QF's) have been coming on line since 1983 in the 10-50 Mw range.

Residential - Over 10 percent of the heat generated in residences comes from wood energy. The market for residential wood use is primarily rural reaching 20 percent of the housing stock and almost 3 percent for urban housing.



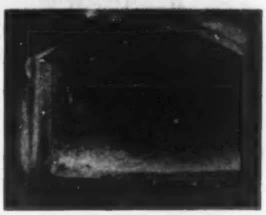
Advanced harvesting and processing techniques could provide another 3-5 quads by the year 2000.

RESOURCE

Wood energy use will rise during the next two decades. Abundant waste wood for fuel has always been present. Residues from existing logging operations and mill, agricultural and urban wastes amount to well over two billion tons annually—or the equivalent of 200,000 Mw of power. Wise management of existing resources will improve the prospects for wood use. Well tended commercial and small forestlands and woodlots could probably yield 3 times as much wood resources through better management, harvesting, and storage practices. Increasing the efficiency of wood energy conversion will have dramatic impacts on the U.S. and world energy supply.

By 1980 wood energy supplied more total energy than nuclear power.

Over the last five years, wood energy has emerged as the technology of choice as a clean, reliable, domestic fuel. Moves towards greater use of wood energy will provide lower energy costs, create more jobs in the U.S., offset oil imports, and enhance America's security.



Existing wood-waste fuels could reasonably supply more than 15 percent of U.S. energy.

NATIONAL WOOD ENERGY ASSOCIATION

Since 1979, the National Wood Energy Association (NWEA) has been the only national trade association for the wood energy industry in the United States. NWEA's members include wood suppliers, equipment and machinery manufacturers, and end-users of wood energy.

NWEA serves as the wood industry's advocate at the federal and state levels. Our association has been the catalyst for tax incentives for wood energy use, reasonable environmental regulatory treatment, and increased access to utility interconnection.

A wide range of services are available to NWEA members such as a complimentary subscription to our national newspaper BIOLOGUE, sales promotion kits and publications, representation at major trade shows, participation in international export programs, and up-to-date political information. NWEA is also chartering affiliated state chapters throughout the United States.

For more information on the National Wood Energy Association, contact NWEA, 1730 North Lynn Street, Suite 610, Arlington, Virginia 22209 (703-524-6104).

NWEA

Mrs. Lloyd. Thank you, Mr. Rinebolt.

Dr. Block.

STATEMENT OF DR. DAVID L. BLOCK, DIRECTOR, FLORIDA SOLAR ENERGY CENTER

Dr. Block. Thank you, Madam Chairman. I want to also thank the Subcommittee for the opportunity to speak today.

I will start my testimony by saying it's not going to be on biomass. I'm grateful that you look for some serious input on policy and hope you will consider my input today in your deliberations. I will try to make my remarks brief and refer you to the written materials for much more detail.

I have picked a theme today which is the story behind the news, the energy story. As you well know, there are many problems that are facing us. Just to name a couple of them, the greenhouse effect, CFCs, lack of affordable housing, regional water wars and certainly problems with toxic and radioactive waste.

These headlines certainly are frightening and possibly appear to represent a system that may be out of control. I think when we take a good, strong look at these headlines and look at the real story behind the news, we begin to see the energy story, and we also begin to see that we have taken many steps, mostly through Congressional initiative to solve these tough, future problems.

Let me examine a couple of these headlines starting with the greenhouse effect. Dr. Klass has already mentioned it as how biomass can affect it. He has already said, as you and I know, that it's primarily caused by the continued worldwide use of fossil fuels.

We must pursue alternatives to fossil fuel, and certainly the two areas that cry out are transportation and electrical generation. Let me just briefly cover these two areas.

In the transportation sector I feel we should immediately undertake a program to consider all alternative fuels and power sources, especially methane, ethanol, hydrogen and electricity. System analyses of all alternative fuels must be performed across the entire spectrum from production to storage to utilization. These analyses must also consider the environmental pollutants and impacts, transitional economic considerations and a maximization of performance, efficiency and maintenance in comparison with obviously petroleum.

Enhanced R&D on hydrogen has already shown progress. Responding to previous Congressional initiatives, the Florida Solar Energy Center, the University of Miami, Texas A&M and the University of Hawaii have been conducting a highly coordinated research effort on production, storage and use of hydrogen from renewable sources.

This current program is unique in that it combines the resources of these four institutions in a program which has been very rigorously reviewed and coordinated and certainly ensures high productivity with no duplication in effort.

This program is rapidly gaining momentum with our current efforts focused on photoelectrochemical and photocatalytical hydrogen production, protobiological hydrogen production, improved storage activities, enhanced liquefaction and the end-use integration and safety analysis.

In the final analysis, only hydrogen-fueled vehicles or those powered with electricity and/or hydrogen produced from renewable resources can meet our long-term concerns. These must be targeted as the nation's future transportation modes. Enhanced R&D for solar electric technologies, biomass and hydrogen from renewables is an absolute must if we are to make this transition.

I will note that we are already being outdistanced by our foreign competition in hydrogen research. Japan and Germany's hydrogen research programs are funded at the $20 to $30 million level, while the U.S. Department of Energy is spending approximately $4 million per year on this effort.

I strongly recommend that Congress continue its support of these present programs and do ask for a small increase in budget for research on this hydrogen from renewables program. This will certainly enhance the hydrogen development work and give us an insurance for the future.

Since 28 percent of the U.S. carbon dioxide output comes from electrical power generations, alternatives for conventional power production must become the focus of intensive research.

Now even more than in the past, Congress must continue support of R&D on solar production of electricity through photovoltaics. Today's cost at 25 cents per kilowatt hour can easily be reduced to the less than 10 cents per kilowatt hour level in the mid-1990's. In fact, each day brings news of increases in new cell efficiencies and lower costs.

Both the cost and efficiency increases require that we be ready in the next decade with the infrastructure that can speed the technology's widespread acceptance and implementation. Congress must be careful of its support of the nation's photovoltaic program, and the total program funding level must not be allowed to fall below the present levels. The U.S. must maintain its broad photovoltaic research support effort.

Let me move just quickly to another issue in the news. Certain headlines about global ozone depletion are appearing as frequently as those about the greenhouse effect. Now the Montreal Protocol gave us hope that the world may finally ban ozone killing CFCs, but ensuring continued industrial and economic growth without the use of these chemicals demands immediate, intensive research on alternatives. The continue growth in the use of air conditioning, a major CFC user, demands research on alternative systems.

While chemical companies are feverishly searching for compounds to replace CFCs, they are not developing alternative systems. Consequently, the government may very well need to fill this vital R&D role.

Through publicly and privately funded research, our center is investigating and demonstrating the feasibility of a variety of innovative solar cooling, dehumidification and air conditioning systems. In one demonstration project we installed an innovative air conditioning system that cut energy use by an astounding 80 percent.

We are looking at other systems that also show significant promise. These are systems that are driven by waste heat, systems that are assisted by power electronics, systems that use liquid desiccants and even a system that actually uses the building as its own cooling mechanism. The majority of this research is supported by the solar buildings program, which I strongly recommend be strengthened, particularly in the area of cooling and dehumidification.

The topics I have discussed have a decided energy slant, and let me highlight just one other issue in which solar energy could play a very beneficial role. This issue is the one of growth that is depleting our fresh water resources. Desalination of salt water through solar-powered reverse osmosis or solar distillation presents a real fresh water production option. Solar distillation technologies are all 15 to 20 years old and they are certainly receiving no attention. No solar-driven reverse osmosis research has been conducted in the last seven years.

Two facts are really clear in my mind.

First, while energy is at the root of many of our environmental, economic and social problems, we can no longer continue to rely on fossil-based energy supplies to resolve them.

Second, most of these problems can be resolved eventually through research on alternative energy. Combining these two facts and we begin to understand the urgent need for development of renewable energy technologies.

I have been discussing some very problematic issues, and let me voice a positive thought in concluding. Even during an Administration that tried to ignore the energy issues, Congress saw beyond the headlines and understood the real story.

If the trend continues, perhaps next year we'll be reading some good news for a change. Congress must provide the momentum to keep this research moving forward, and I highly recommend that funding levels on solar technologies must certainly be maintained to their present level.

Thank you.

[The prepared statement of Dr. Block follows:]

TESTIMONY ON

ALTERNATIVE ENERGY R&D: THE STORY BEHIND THE HEADLINES

by

David L. Block
Director
Florida Solar Energy Center
Cape Canaveral, FL

given before

U.S. House of Representatives
Subcommittee on Energy Research and Development
Committee on Science, Space and Technology

March 2, 1989

I want to thank the subcommittee for this opportunity to speak today. I'm grateful that you look for serious input on setting national energy policy and hope you will consider my testimony to be important in your considerations.

The theme of my address today is the story behind the news. While the public is swayed by every headline, Congress and others responsible for policy must see beyond the news to the real story. My testimony today addresses the real issue behind the headlines: our serious energy problems. Even those concerns about the environment raised by President Bush and Congress in their budget messages last month are energy problems with potential energy solutions.

The headlines say that these are the problems facing Congress: The greenhouse effect and resulting changes in the global climate, chlorofluorocarbons escaping to the atmosphere and depleting the planet's ozone layer, high costs of construction and the lack of affordable housing, trade imbalances and a frighteningly large national debt, drastic business revolutions spurred by deregulation, regional water wars caused by shrinking supplies of fresh water, and continued production and improper disposal of toxic and radioactive wastes that have made whole areas uninhabitable – perhaps forever.

The headlines are frightening; they appear to represent a world out of control. However, when we examine the real story behind the news – the energy story – we see that there are steps we have taken through Congressional initiative and steps we can take in the future to solve these tough issues.

Let's examine the headlines one by one, starting with the greenhouse effect and resulting changes in the global climate. You know, as do I, that the story behind the headlines is the continued worldwide use of fossil-based energy supplies, which is the major driving force in the greenhouse phenomenon. Burning of carbon fuels in the transportation, industrial and power generation sectors increases carbon dioxide, unrecovered methane, nitrous oxide and other emissions. We must pursue alternatives to fossil fuel in these sectors.

In the transportation sector, we should immediately undertake a program to consider all alternative fuels and power sources – methane, methanol, hydrogen and electricity. System analyses of all alternative fuels must be performed across the entire spectrum, from production to storage to utilization. Analyses must also consider environmental pollutants and impacts, transitional economic considerations, and the maximization of performance, efficiency and maintenance in comparison with petroleum.

In the final analysis, only hydrogen-fueled vehicles or those powered with hydrogen and electricity produced from renewable resources can meet our long-term concerns; these must be targeted as the nation's future transportation modes. Keep in mind that our hydrogen fuel of the future must be produced from renewable resources rather than carbon-based fuels; it is the only way to ensure that its production does not create as many problems as it solves. Enhanced R&D for solar electric technologies, biomass and hydrogen from renewables is an absolute must if we are to make the transition from globally polluting to benign transportation.

Enhanced R&D on hydrogen has already shown progress. Responding to previous Congressional initiatives, the Florida Solar Energy Center, the University of Miami, Texas A&M University and the Hawaii Natural Energy Institute have been conducting a highly coordinated research effort on production, storage and use of hydrogen energy from renewable sources.

This research program is rapidly gaining momentum. Our current efforts focus on increasing the efficiency of production methods such as photoelectrochemical processes using semiconductors to split water, photovoltaic-powered electrolyzers and biological water-splitting processes. Another challenge in the program is to develop safe and suitable means of storing hydrogen, since present hydrogen storage methods suffer from weight and economic disadvantages when compared to gasoline storage. The research is currently evaluating storage through metal hydrides, compressed gas and reversible chemical carriers. In the utilization area, we are addressing power cycles and safety considerations, as well as fuel cells, which hold great promise.

Last fall, at the 10th world hydrogen energy conference in Moscow, those in attendance witnessed two surprises. The first occurred when the USSR keynote speakers addressed the greenhouse effect and the huge potential of hydrogen to ameliorate its damage to our environment. In fact, the hydrogen solution to global warming was the chief subject of discussion among the more than 800 scientists in attendance from all over the world. The second surprise was the presentation of a film showing Aleksei A. Tupolev's historic first flight of a modified Soviet TU-155 commercial jet powered only by liquid hydrogen during its entire 21-minute voyage. America's proposed transatmospheric vehicle will certainly have to gain ground to catch up with the Soviets.

In fact, we are being out distanced by other foreign competition as well. Germany and Japan already have larger hydrogen R&D programs. In West Germany, Daimler-Benz and BMW have begun testing hydrogen cars. The Frauenhofer Institute is developing solar-produced hydrogen for heating, cooling and fuel cell electricity for homes. German researchers are evaluating solar energy plants in the Middle East or North Africa that will produce hydrogen for transport to Germany by pipeline or ship -- a project that will carry a price tag of $27 million. Japan's hydrogen research is of the same order as Germany's, while the U.S. Department of Energy is spending $3 million per year on hydrogen research.

With an international consensus already forming on hydrogen, Congress must maintain its support of U.S. hydrogen energy research, particularly as an alternative fuel produced from renewables. The current U.S. program is unique in that it combines the resources of four universities in a program that is rigorously reviewed and coordinated, ensuring high productivity with no duplication in effort. Given such close coordination, even a small increase in funding yields a magnification in results. I strongly recommend that Congress continue its support of the present programs and increase the budget for research on hydrogen from renewables from $2.4 to $3.6 million in the next fiscal year.

While transportation accounts for much worldwide carbon dioxide emission, fully 28 percent of U.S. carbon dioxide output occurs in electric power generation. Alternatives to conventional power production must become the focus of intensive research. Now, even more than in the past, Congress must continue support for R&D on solar production of electricity through photovoltaics, the most promising alternative energy technology in the near term. Material and manufacturing developments have lowered the cost of the technology to a point where solar produced electricity will soon be economically competitive with conventionally generated power. Today's cost at 25 cents per kilowatt hour can easily be reduced to the 6-cents-per-kilowatt-hour level in the mid-1990s. Cell manufacturing costs are already at an all-time low; and each day brings news of increases in cell efficiencies. Sandia National Labs has developed concentrating cells with efficiencies greater than 30 percent, and flat-plate efficiencies will soon be in the 15 percent range using traditional manufacturing processes. These cost and efficiency advances require that we be ready in this decade with an infrastructure that can speed the technology's widespread acceptance and implementation.

Congress must be careful in its support of the nation's photovoltaics program. Total program funding must not be allowed to fall below present levels. I repeat what you already know: Our foreign competitors are far exceeding our expenditures on photovoltaic research. Japan for instance, has been the largest producer of photovoltaics for the past three years. The Japanese recognize the importance of photovoltaics and are now seeking to increase their market share.

The U.S. must maintain a broad photovoltaics research effort. While systems research has always been DOE's lowest priority, from a user's standpoint, systems knowledge is most important because only integrated systems can open new markets and broaden applications. Congress must continue support for testing and advancement of photovoltaic systems and system components. Previous support for the photovoltaic regional experiment stations in Florida and New Mexico has shown very positive results. This work has advanced system design, proved system reliability, built an education and training base, and transferred the technology to industry, government and the public. Congress must see that this work continues.

We've seen that energy is the issue behind news of the greenhouse effect. Headlines about global ozone depletion are appearing as frequently as those about global warming. The Montreal Protocol gave us hope that the world may finally ban ozone-killing CFCs; but ensuring continued industrial and economic growth without the use of these chemicals demands immediate, intensive research on alternatives. And continued growth in the use of air conditioning, which currently accounts for much CFC use, demands research on alternative systems.

While chemical companies are feverishly searching for compounds to replace CFCs, they are not developing alternative systems. Consequently, the government must fill this R&D role.

Through publicly and privately funded research, the Florida Solar Energy Center is investigating and demonstrating the feasibility of truly innovative solar cooling, dehumidification, and air conditioning systems. In one demonstration project, we installed an innovative air conditioning system, which employs NASA-developed heat pipes, at a product warehouse in Georgia. It not only maintains the needed temperature and humidity, it has also cut air conditioning energy use by an astounding 80 percent.

We're looking at other innovative systems that also show significant promise. Examples include systems driven by waste heat, systems assisted by power electronics and liquid desiccants, and even a system that actually makes a building its own cooling mechanism – without the use of CFCs or replacement chemicals. The majority of this research is supported by the solar buildings program. I strongly recommend that the solar buildings program be strengthened, particularly in the area of cooling and dehumidification. The proposed cuts in this meager program, which received $5.4 million last year, will be devastating. Level funding is a must.

Another pressing issue that relates to energy, and that the media have brought to public attention, is the lack of affordable housing in the U.S. A house is "affordable" only if the occupants can pay for the energy it takes to operate it. After all, just like automobiles and other man-made technological miracles, houses ultimately are energy consuming machines. And mortgage and rent subsidies don't pay the utility bills.

With Congressional support, the Florida Solar Energy Center and the University of Oregon have undertaken a research program aimed at significantly decreasing energy use in housing by introducing innovative, industrialized manufacturing technology into the nation's construction practices. The goal of the program is to integrate factory automation techniques in construction – from assembly lines to robotics to computers – along with new materials and designs. The end result will be housing built to such levels of precision and quality that energy savings will be integrally built in to the product without increasing its cost.

This is certainly an ambitious program, but we know it can be done. Sweden, Japan and Denmark are doing it already with remarkable success. In Sweden, for example, fully 96% of all housing is "factory crafted," and those homes are 35% more energy efficient than comparable U.S. housing.

Our research is focussed on determining which industrialized housing technologies will fit into U.S. construction practices and how they can be applied in the nation's extremely varied climate regions. With continued Congressional support, we are confident the project will result in housing that is 25% more efficient with no increase in production costs.

Industry is already responding to our efforts. For example, several large building material manufacturers have expressed interest in applying radiant barriers to their products in the factory. A relatively new technology pioneered by the Florida Solar Energy Center, attic radiant barriers cut air conditioning loads by 15 percent by blocking radiant heat transfer at a cost of a few cents per square foot. Installing them on building components in a factory setting would speed their penetration into the U.S. housing market and increase residential energy savings.

The topics I've discussed have a decided energy slant. However, more and more problems highlighted in the news lately are actually about energy issues, even though their headlines disguise it. Solar energy has a very significant role in resolving these problems. Some examples:

- The headline: Toxic Wastes Accumulating Nationwide. The energy issue: Heat and photon technologies can break down such toxins, but they require large amounts of energy and high temperatures. Solar energy may hold a key in this area. Concentrated solar energy can achieve temperatures greater than normal combustion, thereby more easily and completely decomposing toxic wastes. In addition, solar photon processes can enhance toxic waste decomposition. Unfortunately, no research is currently being conducted on these technologies.

- The headline: Water Wars Heat Up as Supplies Shrink. The energy issue: Growth is depleting our limited fresh-water resources. Desalination of salt water through solar-powered reverse osmosis and solar distillation presents a fresh-water production option. Solar energy can very well be the key to future desalination technology. While reverse osmosis plants are producing 64 million gallons of fresh water per day in Florida alone, not one of these plants is driven by solar energy. Solar distillation technologies, which are 15 to 20 years old, are receiving no research attention, and no solar-driven reverse osmosis research has been conducted in the last 7 years.

CONCLUSIONS

Two facts are clear. First, while energy is at the root of many of our environmental, economic and security-related problems, we can no longer continue to rely on fossil-based energy supplies to resolve them. Second, most of these problems can be resolved eventually through research on alternative energy. Combine these two facts and we begin to understand the urgent need for research and development of renewable energy technologies.

I've been discussing very problematic issues. Let me voice a positive thought in concluding. Even during an administration that tried to ignore energy issues, Congress saw beyond the headlines and understood the real story. If that trend continues, perhaps next year we'll be reading some good news for a change. Congress must provide the momentum to keep this research moving forward. Funding levels for research on alternative energy technologies must be maintained.

PANEL 1 DISCUSSION

Mrs. **Lloyd**. Mr. Rinebolt, in reviewing your testimony you did have a somewhat different approach and you certainly didn't overlap Dr. Klass, but you mentioned tax incentives. What sort of tax incentives would you recommend to help with our renewable energy development?

Mr. **Rinebolt**. I think that the evidence indicates that the 10 percent tax credit on installed capital costs that we had up through '86 was highly effective in getting projects built.

Mrs. **Lloyd**. Did the tax bill sort of do you in?

Mr. **Rinebolt**. It didn't do us in even though the oil prices dropped because it makes economic sense to use biomass in a number of applications. Right now our biggest growth field is in the area where we involve waste disposal.

Mrs. **Lloyd**. I mean on R&D funds that a tax credit would give you.

Mr. **Rinebolt**. It would certainly make my companies more willing to be involved in research type projects. Right now, given the situation with PURPA and the revision of buy-back rates and the cost of capital, they are just keeping their heads above water when it comes to putting projects in the ground, and that's the bottom line. Most of our growth in the wood energy industry is in the small industrial sector right now, and those companies are not going to fund R&D.

Mrs. **Lloyd**. Even with the tax credits?

Mr. **Rinebolt**. With the tax credit I think you will find the manufacturers more willing to get involved in research issues, and certainly we are starting to come together and serious conversion technologies are now reaching the point where they are in scale-up mode, and the type of work that existing companies do is becoming more and more applicable to the research side of the biofuels agenda.

Mrs. **Lloyd**. Very good.

Dr. Klass, you mentioned that the Department of Energy has published their multi-year program plan for biofuels. What is your assessment of this plan with regard to the priorities and the long-term outlook?

Dr. **Klass**. I believe it's a five-year program, and I was involved in reviewing the first and second draft of the plan, and it is a balanced program.

My biggest problem with this plan at the present time is that almost all activities are included in it, and with the very limited amount of funding, it's not going to be possible to conduct research of a quality type on all of these different subjects. So some prioritizing and selection of project activities I think will have to be put into force if this plan is going to be followed.

May I make a comment about your question to Dave on the tax issue. There is a very important tax which is called the energy production tax credit, and I believe it's scheduled to expire in 1990 or 1991. And if this particular credit, which is tied into the price of crude oil can be continued, I think it's going to be a very fine subsidy or tax exemption for all biomass and waste fueled energy production systems.

At the moment I think the subsidy that the energy production tax provides is about 75 cents per million Btu of energy in whatever form it is from biomass or waste, and this is a very large credit to take right off the top as a tax credit, and I think many projects that have been commercialized would not be commercialized today if that credit did not exist.

Mrs. LLOYD. Those tax credits have been beneficial to the industry.

Dr. KLASS. Yes, and I think it also stimulates a lot of additional organizations to get involved in R&D because the project can very often be justified on an economic basis if one includes the energy production tax credit.

Mrs. LLOYD. You stated that you recommend a level of $21.722 million for this year for the biomass program.

Dr. KLASS. Yes.

Mrs. LLOYD. The program is at its lowest level ever for 1990, as you noted. If we were to have a consistent, not a roller coaster budget off and on, but one that you could predict for five years in the future that you knew this was funding that you could rely on, what level of funding could you work with?

Dr. KLASS. Well, if I had my druthers and I could define what the budget should be each year, I would certainly agree that a five-year funding budget would be much preferred over this annual argument that we have as to whether it's too low or too high. This is the best way to plan a short-to-medium term research program.

I would recommend that funding levels of the order of $30 to $40 million per year for biofuels be utilized for each of the five years in question and that would be in the short term. I would, I think, target that particular range, and I know there is some pending legislation that would support this. If this kind of funding were made available, then this multi-year plan that DOE has developed after many months of discussion and argument, the entire program could be put into effect. It cannot be put into effect and into operation with the funding level that has been requested for fiscal 1990.

Mrs. LLOYD. I must have misunderstood you. You requested $22 million for 1990.

Dr. KLASS. Yes.

Mrs. LLOYD. Now my question was could you work at a lower level of funding if you could predict what your funding was going to be for four or five years, and you stated that you would need $30 million.

Dr. KLASS. Well, maybe I misunderstood you. Certain activities of course can be carried out at a defined level of funding. I guess the proper way to state this is that all of the activities currently in progress will not be possible to continue at a level of funding of $9 to $15 or even $20 million. Our recommended level of $21 million plus capital equipment I believe is the minimum amount of funding necessary to continue those projects that we feel are the highest priority and those that are particularly concerned with the production of gaseous and vehicular fuels.

Mrs. LLOYD. Thank you very much.

Dr. Block, it's my understanding that SERI, the Solar Energy Research Institute is doing work in hydrogen research as well. Is their work coordinated with your efforts?

Dr. BLOCK. Yes, very much so.

Mrs. LLOYD. How much is SERI spending on hydrogen research?

Dr. BLOCK. Dr. Hubbard could obviously answer that question better than me, but my estimation is it's approximately $200,000, and it depends on how you count it. I'm talking now of the pure research that they are doing and not the program coordination. The contract work that I mentioned was contracts with SERI. So the DOE money is going through SERI to the four institutions that I mentioned and SERI is also doing work in hydrogen.

Mrs. LLOYD. About how much hydrogen research work is being done by foreign competitors?

Dr. BLOCK. Well, the number that I estimated was somewhere between $25 and $30 million by both Japan and Germany.

Mrs. LLOYD. What's the future of our program, especially since you don't have any Federal research dollars right now.

Dr. BLOCK. Well, there are moderate Federal research dollars in the program.

Mrs. LLOYD. But none requested for this year.

Dr. BLOCK. Not from DOE. I feel the future is very good. I think it's an area that just absolutely has to proceed forward for a variety of reasons, and there are a couple of things on the horizon that I believe really need to be looked at. Certainly the day is going to come when the transatmospheric airplane is going to be a reality. If that day ever does appear, then there is a tremendous amount of work that has to be done on the infrastructure to supply literally hydrogen to fuel that plane. That's probably a niche market which will have to be addressed very shortly. We are trying more to address the more general market or vehicular transportation and the eventual use of hydrogen as one of the primary fuels of the future.

Mrs. LLOYD. Very good. Thank you.

Mr. Morrison.

Mr. MORRISON. Dr. Klass, I was very interested in your concentrated biomass absorption of carbon dioxide. Would you describe that a little more for me. I'm a farmer and what are we talking about?

Dr. KLASS. Well, the statements that I made are basically concerned with the uptake of CO_2 by growing plant material, land-based and water-based plant material. I think the statement that refers to biomass growth being the lowest cost and the most efficient method of removing CO_2 from the environment is probably the essence of the whole subject.

The numbers that are presented in my statement, namely, that 1.2 billion acres of new biomass growth would be sufficient to remove all of the CO_2 produced each year as a result of fossil fuel combustion, that's a pretty interesting number, particularly when you reduce it to a square of area of 1,370 miles on each edge. Now admittedly that's a large area, but I think the fact that about 225 million acres could be made available in the United States itself, land-based area, if other areas could also be made available throughout the world, of maybe not the same size, but possibly smaller, we might be able to tackle the greenhouse effect simply as a result of new biomass production and the removal of the CO_2 produced by combustion.

The other fact to keep in mind, too, is that it doesn't necessarily have to be land area that we're referring to. The oceans are very large, and there are concepts under development that might make it possible to grow aquatic biomass or marine biomass in the oceans and simultaneously remove the CO_2 from the environment. So that is what I tried to convey in the statement, and as an agricultural person I think you can appreciate the impact that this would have on the production of a raw material for energy and other applications as well as the build-up of CO_2 in the environment.

Mr. **Morrison**. Of course, part of the answer, isn't it, is as to how we extract then carbon back out of the accumulation that we have achieved through plants, for instance?

Dr. **Klass**. Yes. Well, in South America, for example, the tropical rain forests of Brazil are being destroyed at a fairly rapid rate, and I think maybe 5 or 10 years ago the size of the tropical rain forests in Brazil were such that the controlling effect that it had on the ambient CO_2 in that area was substantial. It is rapidly going in the other direction now, and it doesn't take much I think to realize what kind of an impact additional biomass growth would have on the removal of CO_2. It is a very large-scale concept, and at the same time it is probably the cheapest way of removing CO_2 if one continued to burn fossil fuels and release new CO_2 into the environment.

Mr. **Morrison**. Of course, ultimately you catch up with that game because you're returning that increased amount of carbon.

Dr. **Klass**. Well, in the case of burning coal, for example, this is old carbon, which takes millions and millions of years for Mother Nature to produce, and as a result the CO_2 that has evolved when the coal was combusted in new CO_2, whereas biomass has a recycling time with respect to CO_2 turnaround that is so short compared to coal production. In effect, there is no new CO_2 added to the environment.

Mr. **Morrison**. Mr. Rinebolt, would you explain this chart which is in the back of your statement.

Mr. **Rinebolt**. Sure, I would be happy to. Actually that chart was developed by SERI and I appended it to my testimony.

You've got the liquid fuels chart, right?

Mr. **Morrison**. I have the liquid fuels, carbon dioxide emissions.

Mr. **Rinebolt**. Okay. What this essentially looks at is it looks at the numbers that are positive on the left side indicating the amount of carbon dioxide released if we replaced existing transportation fuels with what are considered alternative transportation fuels from those various feedstocks. Obviously, methanol from coal releases the highest amount of CO_2 into the atmosphere.

Mr. **Morrison**. With gasoline now from oil being essentially what we are using.

Mr. **Rinebolt**. Exactly.

Mr. **Morrison**. So methanol from coal then is considerably higher.

Mr. **Rinebolt**. Considerably higher. Admittedly, it's a large supply, but it's also a large supply of CO_2. Both the conversion process that produces methanol from coal releases CO_2 and then CO_2 is additionally released when it's burned.

Now, of course, on the negative side of the chart you have ethanol, methanol and gasoline produced from wood. I should point out that SERI has developed a process to produce gasoline from wood at a current estimated price of $1.35 a gallon, and with sufficient research they will be down to the 60 and 70 cents per gallon range producing gasoline from wood, and this is gasoline that fits existing delivery infrastructures. It's essentially identical to gasoline from oil. So we think that shows a lot of promise.

Mr. **Morrison**. And when you throw in regrowth, I presume you're absorbing then what you have produced back out of the atmosphere.

Mr. **Rinebolt**. Yes. That's based on an idea of a fuel cycle using short-rotation forestry to provide the feedstock.

Mr. **Morrison**. So if we started producing gasoline at 60 cents a gallon from wood, and if we grew the trees over again, we would really be in great shape.

Mr. **Rinebolt**. Plus the farmers would make money by growing the trees.

Mr. **Morrison**. I had that in mind, too. [Laughter.]

By the way, we have just introduced a new tax package, since we have been talking about tax incentives, that provides the passive loss rules that apply to wood lot owners, small wood lot owners so you can write off your costs of properly managing that reproduction that we need in America through our forests.

Thank you very much, Madam Chairman.

Mrs. **Lloyd**. Mr. Morrison, I think this man is a good politician. Mr. Smith.

Mr. **Smith** of Texas. Thank you, Madam Chairman.

I have a question for each of the panelists today.

In your prepared testimony and then in the testimony that I have heard today you all have cited the greenhouse effect and global warming as a reason to change our source of energy and as a reason to find an alternative to fossil fuel.

I guess my question for you all is isn't that a pretty thin reed on which to base a recommendation that would have such a dramatic impact on our economy considering that the testimony regarding the greenhouse effect and global warming is very conflicting and there doesn't seem to be anything definitive as far as either the length of the warming or whether or not there really is a warming trend at all?

Dr. **Klass**. Let me respond to your question and comments first. In my statement I qualify the statements that I make by saying if the greenhouse effect is indeed real or statements of that type. I agree with you, I don't think there is a unanimous agreement that the greenhouse effect is real yet, but certainly something is going on, particularly in the area that I'm from, and I expect that if it happens again this coming summer, we are going to have to probably reinforce the consensus that we have right now and possibly make this a much more uniform conclusion that several people have reached, namely, that the greenhouse effect is real.

I don't know if we can ever use the data that has been developed to date to reach a firm conclusion. It's going to take a number of years I think in additional information to support this whole idea.

What I tried to point out in my statement regarding biofuels usage and biomass growth, is that both of these endeavors can have a decided impact on the removal of CO_2 and on the control of global parameters, such as temperature, if we ultimately start to get away from the use of fossil fuels as our primary energy source, and I think eventually this is going to happen, but it's not going to happen in the next 5 to 10 years. It's going to be a long period of time. And by then we certainly, maybe 20 or 25 years from now, will know whether or not the greenhouse effect is real.

Mr. SMITH of Texas. I appreciate that.

Mr. Rinebolt.

Mr. RINEBOLT. Congressman, having looked at the evidence, I think that the concept that the atmosphere loading of CO_2 is going to have some impact in the future weather patterns in the world, the evidence is I think pretty much unanimous that it will to some extent.

I think that your question as to the impacts of it is also accurate. We don't know what is going to happen exactly, but I'm a realist, and I'm not here advocating a crash program that we replace all oil and gas with biomass based fuels. I think that's absurd, and the economic dislocation and disruption that would be engendered by such a massive government program is not justified based on the current evidence and probably wouldn't solve the problem.

What I'm saying is that biomass is a niche fuel, and it serves a purpose in this country because we are already producing wood wastes, we are producing agricultural residue and it's 25 percent of our municipal waste streams.

Now given that this material is going to decompose in the forests anyway, I think it behooves us, given the fact that the indications are that CO_2 loading is a problem, to begin to manage our forest resources and our agricultural resources in such a way that we cycle CO_2 out of the atmosphere in an economically efficient manner and when it is economically efficient to use biomass and to use wood for energy that we use it because there is a positive effect and it can be an ameliorative effect on the problem.

I think overall my perception of our energy future is that both fossil and biofuels combustion are a short to mid-term solution to our energy problems, and that in the future, 100 years from now or 200 years from how we'll be solar powered and we'll be hydrogen powered, fuels that don't result in the release of any contaminants into our environment.

In the near term we are looking for bridge fuels to partially solve the situation, and I think that biofuels is a cost effective mechanism for that.

Mr. SMITH of Texas. Thank you.

Dr. Block.

Dr. BLOCK. Well, I think the previous gentleman's two answers are very close to what I would pretty much say. If you look at the levels we're talking about, we certainly would make no pretense that for the amounts of money we are asking that you can solve the replacement of fossil fuels with that level of activity. I think it's intended to be an R&D effort and has to be taken as an R&D effort.

I use the example of the transistor as a classic case of a device which took 35 years to go from the laboratory to full-scale use. The energy crisis has been with us from 1973. So why do we expect in 15 years that either biomass or hydrogen and/or photovoltaics is going to be in the market when the transistor took 35 years. So I think it's a problem which we as a nation have to look at and we have to recognize. I think that's what my intention is, to encourage us to continue this activity forward and not to drop it, and I believe the levelized funding concepts really begin to make some sense so we can try to look at the long term.

Mr. SMITH of Texas. I'm reassured by your answers. Thank you. Thank you, Madam Chairman.

Mrs. LLOYD. Thank you very much, Mr. Smith.

Mr. Walker, we are very happy that the Senior Republican on the full Science and Space Committee does come to our hearings and take part. We do appreciate you being here, Mr. Walker.

Mr. WALKER. Thank you, Madam Chairman.

Dr. Block, I would like to talk a little bit about hydrogen with you. Were you at the conference in Moscow?

Dr. BLOCK. Yes.

Mr. WALKER. At that conference there were 800 scientists from around the world there who are reasonably high on the idea that hydrogen can be utilized as an energy source.

Dr. BLOCK. Correct.

Mr. WALKER. And you actually saw demonstrated there a commercial jet that is powered by liquid hydrogen?

Dr. BLOCK. It was not actually demonstrated. It was a movie.

Mr. WALKER. It was a film of liquid hydrogen that has been done by the Soviets?

Dr. BLOCK. That's correct.

Mr. WALKER. And Germany and Japan both have hydrogen programs that are producing hydrogen-based cars at the present time?

Dr. BLOCK. They actually have some manufacturers, and I saw at the hydrogen conference, one was a Mercedez, and Toshiba and I believe Mitsubishi all had fairly illustrative displays of hydrogen-powered vehicles that they had at least on an experimental R&D basis developed.

Mr. WALKER. German is spending about $27 million a year and Japan is spending about $27 million a year on hydrogen-based research, and we are spending about 10 percent of that in this country?

Dr. BLOCK. Yes.

Mr. WALKER. Now if I take all of that and kind of put it together, let me see if I'm right. There is a body of scientists worldwide who believe that this is a potential energy source that can serve mass needs; is that a fair statement?

Dr. BLOCK. Yes.

Mr. WALKER. There is technology at least at the fundamental level which shows that hydrogen-based engines can work.

Dr. BLOCK. No question.

Mr. WALKER. And that there is considerable research going on among our competitive allies and some of our adversaries doing intensive research into this area; is that correct?

Dr. BLOCK. Correct.

Mr. WALKER. Now what are the main problems that have to be overcome in a research program? In other words, if we were to invest more money in hydrogen-based research, what are the main problems that have to be overcome in order to get us a hydrogen energy economy?

Dr. BLOCK. Well, there are basically three areas. The three areas that have to have work are the production of hydrogen, the storage of it and the utilization. Hydrogen is more than a fuel. It also is a storage medium. So the two critical areas are the production area and the storage area.

Mr. **Walker**. So we basically have to have something similar to gasoline refineries and we would have to create massive production facilities.

Dr. **Block**. Well, I'm not saying that we don't produce it now. We do produce it now.

Mr. **Walker**. But not in the quantities that would be used for mobile transportation.

Dr. **Block**. That's correct. Basically we produce it today from fossil fuel resources. If you look at the Space Shuttle, for example, it gets its hydrogen from steam reformation of natural gas. Now in my mind it makes no sense at all to take natural gas and reform it into hydrogen and burn it. I mean you might as well burn natural gas in the vehicle straight out. I mean there is no sense in going through the process. So you've got to produce hydrogen from a process that is not fossil fuel driven, and that gets kind of in the argument a little bit with the concept of coal.

Now you could take coal and produce hydrogen from coal in some sort of reforming process, and you could say well, I could therefore make coal into a liquid fuel, and I guess that would be a valid way of doing it if you wanted to.

The idea that we are trying to put forth is that you really need to produce the hydrogen from renewable resources. That's the key.

Mr. **Walker**. Is that the research that is being done by our allies and by our adversaries? I mean are they at this point producing the hydrogen, or is their research aimed at producing hydrogen from new sources?

Dr. **Block**. There is a piece of that in all of the programs, but to be frankly honest with you, the impression that I left Moscow with was that most of the Russian scientists were spending their effort on coal gasification processes.

There is no question that we are looking at it, and in fact if you look at the coal part of the DOE budget, you'll find that it greatly outstrips the whole solar budget.

Mr. **Walker**. Now I assume that the storage side of it is simply the safety side.

Dr. **Block**. No, it's not safety. It's partially, but hydrogen, the safety part of hydrogen is really not a very severe problem. It's only a bad problem because everybody remembers the Hindenberg. If we could erase the Hindenberg from most people's minds, the fact is that hydrogen is no worse than gasoline.

But the storage problem is a real problem if you say that I want to have an equivalency with gasoline. If you get a container that weighs maybe 10 times more than the same gasoline container, that's the area that we have to look at. In other words, we need to get hydrogen to a case where it's similar to what we think of as a tank of gasoline to be truly competitive or you pay too big a penalty.

Mr. **Walker**. You mentioned the transatmospheric plane in your testimony. One of the advantages then of proceeding in that direction would be that we would have to put together exactly that kind of infrastructure in order to do a transatmospheric plane, because obviously that's going to be a hydrogen-powered vehicle with scram jets required.

Dr. **Block**. The transatmospheric plane will require hydrogen. It's literally the only fuel that will be able to perform in this——

Mr. **Walker**. And you would have to create some of the infrastructure that you're talking about simply to have that in place.

Dr. **Block**. Oh, yes, of course.

Mr. **Walker**. I was at Edwards Air Force Base recently, and that is one of the concerns out there even for the initial couple of national aerospace planes that we are going to produce. They don't have anything in place that would give them the capacity to service and fuel a hydrogen-powered craft. So I mean that is one of the things that they are already having to look at.

Dr. **Block**. There are only two places, to my knowledge, and that's Kennedy Space Center and Edwards Air Force Base that has that capability and that's it.

Mr. **Walker**. Thank you, Madam Chairman.

Mrs. **Lloyd**. Thank you very much, Mr. Walker.

I want to thank the panel for being with us today. Your testimony was excellent, and we certain appreciate your insight and your knowledge.

Our second panel includes Mr. Scott Sklar, Executive Director of the Solar Energy Industries Association; Mr. Joseph Hutchinson, President of Solar Kinetics; and Dr. Harold Hubbard, who is the Director of Solar Energy Research Institute.

Gentlemen, you have appeared before us before and we look forward to hearing your testimony again today.

Panel 2

STATEMENT OF SCOTT SKLAR, EXECUTIVE DIRECTOR, SOLAR ENERGY INDUSTRIES ASSOCIATION

Mr. **Sklar**. Thank you, Madam Chairman. I always appreciate having the opportunity to testify before this Subcommittee.

Mrs. **Lloyd**. Well, it's always good to see you back with us.

Mr. **Sklar**. The Solar Energy Industries Association is the national trade association for the photovoltaics and solar thermal manufacturers and components suppliers.

I would first like to thank Representative Lloyd and Morrison for introducing the Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989. That's a mouthful. But it is an important piece of legislation and we thank you both for being in the vanguard of support for maintaining our U.S. renewable energy efforts.

As I testified last year in front of the Subcommittee, our international competitors are beginning to outspend us in government-sponsored solar R&D. As I said last year, Japan and Germany for the first time outspends the United States in photovoltaic R&D. The European Consortium, Phoebus, has now selected Jordan as its site for a 30 megawatt solar central receiver plant using stretched membrane technology, again commercializing technology I believe ahead of the United States. And Japan and many of the Scandinavian countries may outspend the United States on smart glass, electrochromic glass which we can use to enhance solar water heating and passive solar housing.

There is a competitiveness threat here and, as you know, the solar energy industry does not believe that Federal R&D support has either been consistent, reliable or balanced among energy technologies, and every year I bring nice colored graphs up here to show you one thing or the other, and today it's just comparing Federal R&D trends for the technology.

As you can see, the only one that is really going down, down, down, down is the third one from the left, and that is the renewable budgets every year. I know you are sensitive to that, because obviously that is why the legislation went in.

On page 2 of my testimony I have enclosed a graph of the actual solar budget of the solar buildings, photovoltaics and solar thermal programs for the few years to give you a sense.

On page 3 of my testimony I really outlined the progress of photovoltaics, and on page 11 I list the 20 world breakthroughs, the world record breakthroughs of photovoltaic efficiency that the United States has done. And that's on page 11, we have had 20 breakthroughs last year on photovoltaics efficiency as a result of the DOE program.

On page 12 I include a set of accomplishments for that year. The photovoltaic program is well managed, has good industry support and my sense is if we can just maintain level R&D, you will have a world class industry here.

You may have noted last week in the Wall Street Journal a full-page ad about Atlantic Richfield may sell its Arco Solar subsidiary to the Japanese or Germans. It's our nation's largest photovoltaic manufacturing facility, and although it's profitable in terms of sales, the company spokesman said that when you take in the R&D expenditures into account, it's less favorable.

The bottom line is this is industry wide. The Government is going to back out of research, they will need to do more, and if they need to do more, they are going to question whether they are going to stay in the business. The fact of the matter is that the $10.5 million cut that OMB is requesting, 30 percent of our budget, would render that program useless, particularly in the face of a $60 million-plus budget in Germany and a $40 million-plus budget in Japan.

So my message is just sort of very clear that if you want a U.S. industry to stay into this and private investment, we are going to at least have to maintain a level response over some years.

On pages 9 and 10 of my testimony I put out a series of graphs on charts of solar thermal trough, heliostat and dish technology, and you can look at those charts, and it goes down, down, down, sort of like funding for the solar energy budgets. But those charts are good because prices are going down, and again as a direct result of the program.

I would also like to point out and have included in the record the article today in the Washington Post which outlines the success of putting 196 megawatts on the grid of solar thermal power technology. The issue here is it came directly out of the R&D program at DOE. It's a solid technology, and the new stretched-membrane technology for troughs and mirrors and heat engine programs will even give us bigger breakthroughs and have more solar electricity on the grid, and that's great.

Now this small $15 million budget has been cut 80 percent over the last eight years. OMB wants to cut it two more, and again my message is the same, you do that and you will render the program rather worthless.

Lastly, on pages 13 and 14 of my testimony I include some of the description work at SERI mostly on the solar SMART glass glazing work and solar desiccant work at SERI. Again this small $5.4 million budget now has been sort of levelized at what I believe is a close-out level over the last three years, and OMB comes out again and wants to cut 20 percent off of this little budget.

The fact of the matter is again the Germans and Japanese are going to commercialize electrochromic glass, make a few billion dollars off of technology that we created, and we ought to maintain it.

Finally, I cover the international programs, a small $1 million program. That is the only program within DOE that looks at the short-term market, and it supports the Committee on Renewable Energy and Commerce and Trade, which is the Federal interagency group established to promote exports for all the renewable energy industries. It is supported by the industry umbrella group of nine renewable energy trade associations, the U.S. Export Council for Renewable Energy, as one of the most cost effective bang-for-the-buck programs, and indeed they want at OMB to cut that program in half from one to half a million dollars, and it probably should be increased a half a million dollars.

We will be hosting this year in May of 1989 our first renewable energy trade show sponsored by 13 Federal agencies, nine of the renewable trade associations geared to build export markets in the Caribbean to actually commercialize these technologies. The Department of Commerce and U.S.A.I.D. are bringing the private sector and government sector purchasers there and we should have a fairly good sales experience as a basis of this.

My conclusion to the Committee is pretty clear.

One, we've got to maintain R&D funding in all these sectors. We are not asking for more money. We are just asking to have level funding.

Secondly, we need an authorization bill out of your Committee this year, and when we go and testify in front of the Appropriations Subcommittees, they always respond that they have no direction out of the authorizing Committees. We desperately need a bill.

And, lastly, if we fail to do this, and this I believe is the threshold year for the United States, this 1989 year, if we are unable because of Gramm-Rudman-Hollings or other pressures in the DOE budget that I know you have to contend with, and I sympathize with you over, the fact of the matter is you will be importing all this technology after the year 2000, and I believe that personally, not only in solar, but all the renewables, and that would be a real tragedy.

Thank you very much for hearing me.

[The prepared statement of Mr. Sklar follows:]

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TESTIMONY

by

SCOTT SKLAR
EXECUTIVE DIRECTOR
SOLAR ENERGY INDUSTRIES ASSOCIATION

before

HOUSE SCIENCE SPACE & TECHNOLOGY COMMITTEE
SUBCOMMITTEE ON ENERGY RESEARCH & DEVELOPMENT

MARCH 2, 1989
WASHINGTON, D.C.

INTRODUCTION

The United States is facing a crises that may very well determine our place as a world economic power in the 1990's. Although we possess great technical creativity, we seem unable to commercialize our discoveries in the marketplace and as a result, we have seen our international competitors commercialize our creations and reap the billions of dollars and millions of jobs from these endeavors.

The American people are about to witness a replay of this sorry state of affairs in our handling of the federal solar research and development programs. Virtually every industrialized country has increased their federal R&D in solar energy technology. The German and Japanese governments surpassed U.S. photovoltaics R&D for the first time in 1988. The Spanish and Swedish governments surpassed U.S. solar thermal power R&D also in 1988. The Danish and Swiss governments surpassed U.S. solar buildings R&D in 1989.

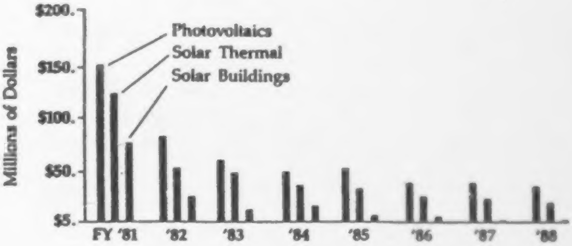
The new Administration has requested a 30 percent cut for photovoltaics research from $35.5 million in FY'89 to $25.0 million in FY'90, which has already been cut yearly from $155.0 million since FY'81. The Administration also has proposed cuts of 15 percent for solar thermal power research from $15 million in FY'89 to $13 million in FY'90 which has been cut yearly from $121 million since FY'81. The Administration has recommended a 20 percent cut in the solar buildings research program from $5.4 million in FY'89 to $4.2 million in FY'90 which has been cut yearly from $77 million since FY'81.

Why in the face of increased international competition and major concerns about global climate change is the United States essentially closing down its federal solar research programs? Why have the solar programs sustained far greater cuts than other federal energy research & development programs? Why would the United States slash research programs at a time when these technologies are becoming cost-competitive in the marketplace?

The years of 1989/1990 will determine whether the United States will have a domestic solar energy industry or relinquish its technological leadership to our international competitors. Our country faces the real possibility of importing solar technologies in the years when they become fully cost-competitive. From my point-of-view, the United States lacks an effective energy policy and has biased priorities against maintaining our technical predominance and development of solar and renewable energy technologies. This bias is exemplified by the Administration's request to cut the $352 civilian nuclear energy research budget by only $2 million in FY'90 in contrast to their request to cut the aggregated solar budgets of $56.9 million by $13.2 million.

At some point, the U.S. Congress must come to terms as to whether you want to maintain a United States solar energy research effort. The U.S. Congress must also come to terms that at some level, lower solar budgets will not be effective in furthering the technology. The Solar Energy Industries Association, the national trade organization of the photovoltaic and solar thermal manufacturers & component suppliers, believes that the FY'89 funding levels are that bottom line. Therefore, the U.S. solar energy industry asks this Committee to hold the line, maintain an effective U.S. solar energy effort, and come to grips with the reality that if the United States does not push the technology out of the research pipeline, our international competitors will, and the United States will be totally reliant on our competitors for solar technologies for generations to come. Congressional actions in these two years will determine the outcome since the Administration has shown a "business as usual" approach.

Trends in Federal Solar R&D FY '81 - FY '88

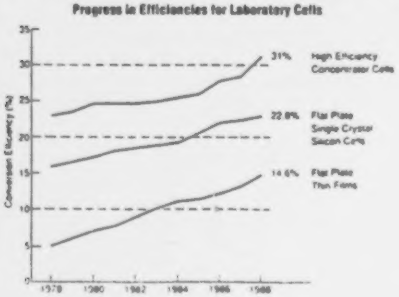


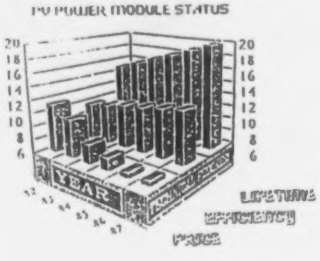
PHOTOVOLTAICS

The United States photovoltaics program has three basic thrusts: Bring down the costs of the technology through increased efficiency through the development of new materials and processes in manufacturing photovoltaic cells; Assist the industry in cost-shared research to commercialize research developments; and provide design assistance & review for large-scale photovoltaic systems for export, and government & utility procurement.

As you can see in the addenda, the photovoltiacs program has made great strides with over twenty world efficiency records of photovoltaic cells and modules. The chart below summarizes the cost reductions and the increases in lifetime & efficiency over the last six years as a result of the research program. The United States has maintained our technological lead worldwide due directly these research efforts. However, while the U.S. photovoltaic marketshare has been maintained through level funding during the FY'88-89 years, the precipitous cuts recommended by the White House (30%) will undercut the U.S. industry so badly that it is very unlikely the industry would ever recover. I cannot emphasize enough to this Subcommittee, that whatever the Congress decides has profound effect on the private investment markets. When Congress maintained level photovoltaic research monies in FY'89, increased private capital flowed to our industry. If Congress cuts this small research program, the private markets will sense that the United States government lacks the resolve to commercialize photovoltaic technology, and disinvestment will occur. Program cuts will insure that the United States will lose both our technological and market leads to both Germany and Japan.

The U.S. Department of Energy Photovoltaic Program has been effectively managed, and has developed an excellent relationship with the private sector. The national laboratory and university efforts are effectively integrated into the research program. This R&D program is a model on how best to commercialize high-technology. Funding for FY'90 should be increased to $40 million or at least maintained at the current $35.5 million level.





SOLAR BUILDINGS

The U.S. Department of Energy Solar Buildings Program is the smallest of the research and development programs and has been essentially at a closedown level of $5.4 million over the last few years. While buildings consume nearly 35 percent of U.S. energy and produce more greenhouse gases than the U.S. utility sector, this energy research area receives the least support. While the United States sits idly by, our international competitors in Scandanavia and Japan have geared up to commercialize energy efficiency technologies which have already begun to enter the United States market.

The solar building research effort has centered on three basic research areas: Solar cooling research using desiccant cooling technologies and new polymers in desiccants which can absorb up to 2000 percent of their own weight, efficiently dehumidify air thus providing cost-effective space cooling. The result of this research will save consumers millions of dollars for space cooling as well as saving utilities from building costly power plants to meet daytime cooling demands.

The second research area focusses on both passive and active solar design assistance. The Solar Energy Research Institute has worked with industry to develop a computerized energy simulation program for seven building types in two climate zones. This computer program will help builders select cost-effective passive solar applications in our nation's buildings. Under US/DOE auspices, SEIA and ASHRAE have developed a commercial-scale solar water heating design manual based on our experience over a decade with solar systems on federal and commercial buildings. In 1989, SEIA/DOE will develop and publish companion installation and operations/maintainance manuals for these large-scale systems. The final program thrust involves research on electrochromic or "smart" windows. By deposing an transparant metal-oxide material on glass, cooling costs for both buildings and automobiles may be significantly lowered. This technology along with photochromic glass has useful potential in the active solar industry in making collector glazings more efficient.

The potential markets for energy efficient technologies are extraordinary. But again, if the United States does not have the interest to commercialize these technologies, our competitors will. Does the United States have the resolve to follow-through on its research? Only the U.S. Congress can answer this question.

SOLAR THERMAL POWER

The United States now has 200 megawatts of completely private sector financed solar-steam-to-electricity utility-grade power plants. The solar trough concentrators used derive directly from US/DOE-sponsored research. This glass technology will soon be superceded by US/DOE developed stretched membrane technology utilizing a silver-coated polymer. The polymers will reduce the cost of this technology even further. Utilities are utilizing solar thermal technology for peak-power applications because they produce the most power during the utility's greatest demand for electricity (noontime), and they have minimal regulatory obstacles due to their cleanliness (no polluting emissions) and surety of supply (sunlight) that they can be constructed within fifteen months.

The U.S. Department of Energy Solar Thermal Power Program has three major program thrusts. First, the program will finish the upgrading of stretched membrane dishes and heliostats to efficiently concentrate sunlight. Actual trial tests are necessary to assess research progress and permit fine tuning. Secondly, second generation work to develop working solar dish concentrators which focus sunlight on engines that are capable of running electric generators, is being pursued through industry joint ventures. Finally, technology spin-offs to power lasers and detoxify wastes will be aggresively pursued as a new cost-effective high value market for these technologies.

The solar thermal technologies are also being commercialized by our industrial competitors. The European Consortium, Phoebus, plans to build a 30 megawatt solar central receiver tower in Jordon using stretched membrane heliostats. Such a venture by European governments may thrust European industries as the major commercializers worldwide of this technology.

The Solar Thermal Power Program should be funded at the $20 million level in FY'90 to remain competitive. A minimum of $17.5 million is necessary just to maintain ongoing programs. Cuts to $13 million as proposed by the Administration would effectively cut out the U.S. industry from federal research efforts and just support limited laboratory work that may never be commercialized. Price breakthroughs, so far, have been very promising as shown in the charts in the addenda taken from the August 1988 Report to Congress titled, "Bringing Solar Thermal Technology to the Marketplace".

Solar thermal power technologies have shown that they are competitive in the peak power utility markets today. New advances in technology will make them even more competitive. The world markets offer a virtually unlimited opportunity to successfully commercialize these technologies. Solar thermal power offers a competitive way not only to produce electric power but detoxify hazardous wastes, accomplished successfully by Sandia National Laboratories in 1988. Successfull experiments by the Solar Energy Research Institute in 1988 which concentrated sunlight 60,000 times, enough to power lasers, is a breakthrough important to pursue.

The Solar Thermal Power Program has an effective working relationship between the primary national laboratories, the Solar Energy Research Institute (SERI), Sandia National Laboratories, and the U.S. solar thermal industry. The research program deserves higher consideration by the Congress as an important element of federal research.

INTERNATIONAL

The international line item of the U.S. Department of Energy supports multiagency activities mandated under P.L. 97-370 which created the federal interagency board, The Committee on Renewable Energy Commerce and Trade (CORECT) to coordinate federal efforts to promote solar & renewable energy exports. This small $1 million program leverages more money than any renewable energy program in the U.S. Department of Energy Conservation & Renewable Energy program.

Aside from a series of trade missions and education materials, the program is supporting a conference and trade show in May 1989 to promote U.S. renewable energy technology & services in the Caribbean Basin & Latin America. The program coordinated by the U.S. renewable energy trade association umbrella group, the U.S. Export Council for Renewable Energy (US/ECRE), is the first of a series of market sector promotion program geared to meet increasing international competition from our international competitors.

The $1 million program should be increased to $2.5 million rather than cut to $0.5 million as recommended by the Administration. For the last eight years, the United States renewable energy effort was focussed, wrongly, on long-term, high risk, research & development. This small program is the only short term government effort to meet our competition head-on. The international program ought to be preserved and enhanced.

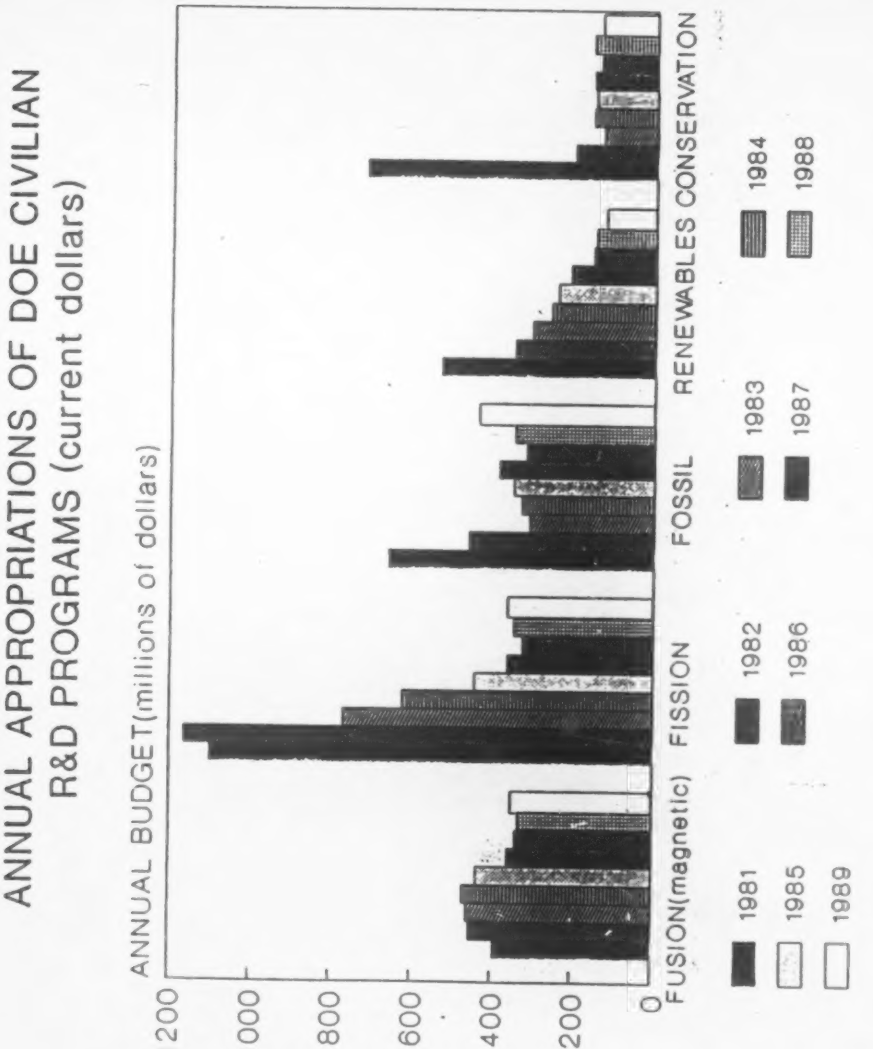
CONCLUSION

The United States has reached a time of reckoning regarding whether our nation is committed to realize its federal R&D investment over the last fifteen years, or relinqish our technological lead and the potential multibillion world markets for solar energy technologies. At minimum, the United States must restore $13.5 million worth of recommended cuts for FY'90 and at best add another $10.5 million more dollars to effectively bring these technologies effectively to the marketplace.

Obviously, budgets are tight but the $24 million needed to effectively bring these technologies to the marketplace and maintain the United States' technological lead, can easily be pulled from ongoing U.S. Department of Energy civilian R&D programs.

In the photovoltaics program, every goal on price and efficiency has been met by the research program. In the solar thermal power program, exciting new breakthroughs on cost, toxic waste breakdown, and laser powering add increasing value to this unique program. The solar buildings program has yielded important tools for the building community to utilize passive and active solar technologies as well as high-technology window & desciccant applications. Finally, the international program offers the best "bang for the buck" in building international markets for U.S. technology and services.

Hopefully, the Congress will re-evaluate policies and funding of the solar research & development programs, and will seek to maintain the United States lead in this technology. Other initiatives to promote government/industry joint ventures, enhanced federal government procurement and export promotion would also be very welcome.

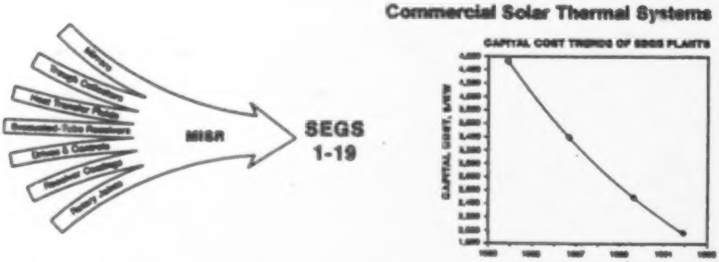


ANNUAL APPROPRIATIONS OF DOE CIVILIAN R&D PROGRAMS (current dollars)

SOLAR THERMAL RESEARCH & DEVELOPMENT

As illustrated below, innovations in materials and components for parabolic troughs were integrated into and proven by the DOE Modular Industrial Solar Retrofit (MISR) systems. These enabling technologies encouraged Luz to employ these component improvements in its commercial systems. As innovations were incorporated into successive commercial systems, each new generation reflected lower system capital costs and lower energy production costs as illustrated. Luz is now considering further reductions in cost by replacing hybrid solar/gas steam generators with storage systems currently under development by DOE. Specific feedback of this kind is incorporated into the DOE research and development program and strengthens industry's ability to continue deployment of systems in broader applications with increased user confidence.

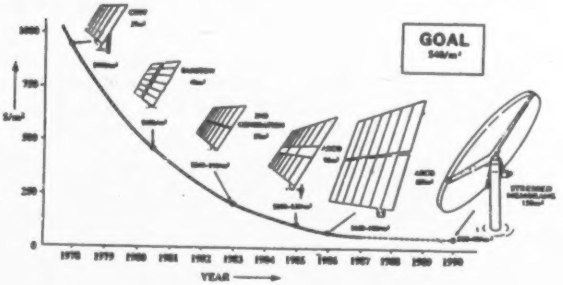
Commercial Solar Thermal Systems


Mirrors
Trough Collectors
Heat Transfer Fluids
Evacuated-Tube Receivers
Drives & Controls
Receiver Coatings
Rotary Joints
MISR
SEGS
1-19
CAPITAL COST TRENDS OF SEGS PLANTS
CAPITAL COST, $/kW

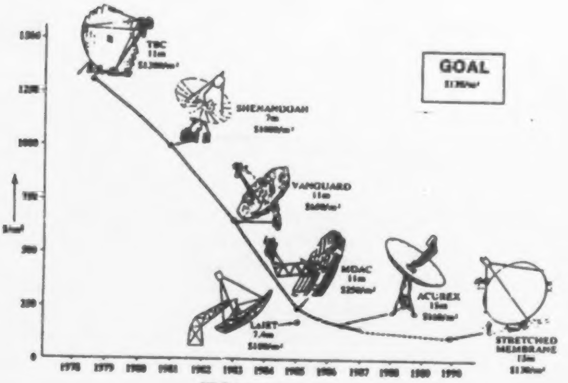
Such processes, in the longer term, also allow solar thermal systems to enter advanced applications such as hazardous waste destruction, materials processing and fuels and chemicals processing. While prototype solar thermal systems have not been tested in these applications, industrial manufacturers of concentrators have begun to see how the low-cost membrane dish concentrators and central receiver technology can directly be used to conduct chemical reactions in a receiver/reactor. Laboratory data have encouraged industry to begin to develop plans and assess the market potential for integrating solar thermal systems into these emerging applications which have national importance.

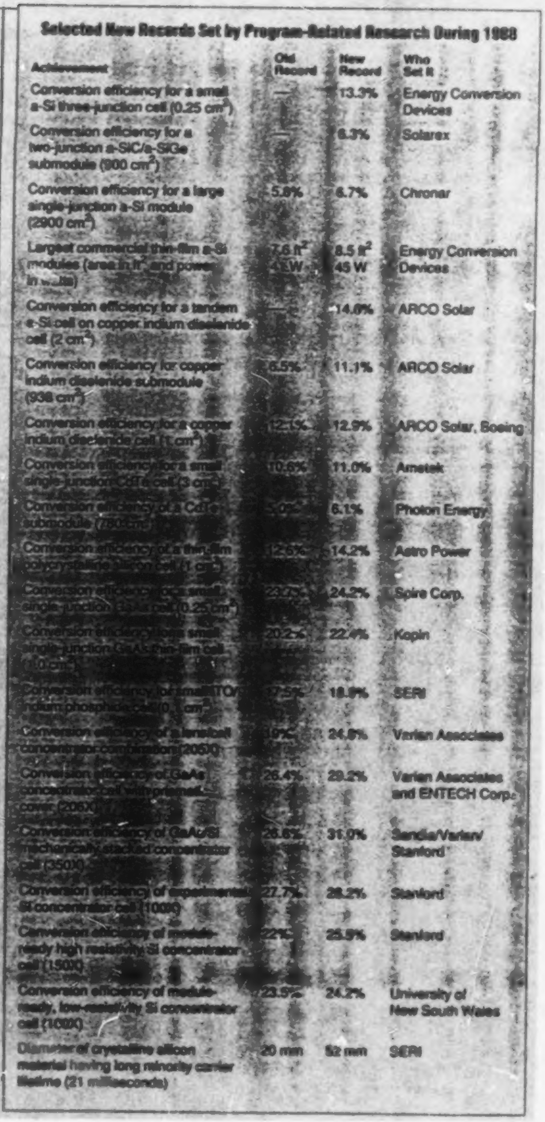
Receivers for solar thermal systems have also evolved during the past decade. Initially small-scale field experiments were needed to investigate the feasibility of using tube receivers to produce steam. In the early 1980s a scaled-up water/steam receiver was deployed in the 10-megawatt Solar One Pilot Plant, a systems experiment developed by DOE in conjunction with Southern California Edison Utility Company. Today's R&D efforts are aimed at further reducing receiver costs through the use of advanced designs and molten salts as the heat transfer fluid.

Progress In Heliostat R&D



Progress In Dish Collector R&D





Selected New Records Set by Program-Related Research During 1988

Achievement	Old Record	New Record	Who Set It
Conversion efficiency for a small a-Si three-junction cell (0.25 cm²)	—	13.3%	Energy Conversion Devices
Conversion efficiency for a two-junction a-SiC/a-SiGe submodule (900 cm²)	—	8.3%	Solarex
Conversion efficiency for a large single-junction a-Si module (2900 cm²)	5.8%	6.7%	Chronar
Largest commercial thin-film a-Si modules (area in ft² and power in watts)	7.6 ft² 43 W	8.5 ft² 45 W	Energy Conversion Devices
Conversion efficiency for a tandem a-Si cell on copper indium diselenide cell (2 cm²)	—	14.6%	ARCO Solar
Conversion efficiency for copper indium diselenide submodule (938 cm²)	6.5%	11.1%	ARCO Solar
Conversion efficiency for a copper indium diselenide cell (1 cm²)	12.1%	12.9%	ARCO Solar, Boeing
Conversion efficiency for a small single-junction CdTe cell (3 cm²)	10.6%	11.0%	Ametek
Conversion efficiency of a CdTe submodule (780 cm²)	5.0%	6.1%	Photon Energy
Conversion efficiency of a thin-film polycrystalline silicon cell (1 cm²)	12.5%	14.2%	Astro Power
Conversion efficiency for a small single-junction GaAs cell (0.25 cm²)	23.7%	24.2%	Spire Corp.
Conversion efficiency for a small single-junction GaAs thin-film cell (1.0 cm²)	20.2%	22.4%	Kopin
Conversion efficiency for small ITO/indium phosphide cell (0.1 cm²)	17.5%	18.8%	SERI
Conversion efficiency of a lens/cell concentrator combination (205X)	19%	24.8%	Varian Associates
Conversion efficiency of GaAs concentrator cell with prismatic cover (206X)	26.4%	29.2%	Varian Associates and ENTECH Corp.
Conversion efficiency of GaAs/Si mechanically stacked concentrator cell (350X)	26.6%	31.0%	Sandia/Varian/Stanford
Conversion efficiency of experimental Si concentrator cell (100X)	27.7%	28.2%	Stanford
Conversion efficiency of module-ready high resistivity Si concentrator cell (150X)	22%	25.5%	Stanford
Conversion efficiency of module-ready, low-resistivity Si concentrator cell (100X)	23.5%	24.2%	University of New South Wales
Diameter of crystalline silicon material having long minority carrier lifetime (21 milliseconds)	20 mm	52 mm	SERI

Progress in Research - 1988

Fundamental and Supporting Research

Achieved 19% efficiency for AlGaAs cells through cooperative project (Kopin, Research Triangle Institute, SERI)

Created mathematical model to explain loss mechanisms in CIS and CdTe cells, revealing areas for efficiency improvements (Colorado State University)

Performed more than 8000 material/cell/module tests and measurements for more than 100 different organizations (SERI)

Developed spectroscopic scanning tunneling microscope method for the direct imaging of atoms in electronic solids (SERI)

Optimized a method to measure microvoids in good-quality amorphous silicon, to help manufacturers improve photostability (SERI)

Grew high-quality gallium phosphide on silicon with greatly reduced defect density (SERI)

Predicted theoretically that novel semiconductor compounds can be stabilized epitaxially, and may be useful as new photovoltaic materials (SERI)

Initiated a cooperative effort to study single-crystal CIS cells (SERI, Institute of Energy Conversion, ARCO Solar)

Improved technique used to measure electron energy levels (Carnegie Mellon)

Patented the Atmospheric Optical Calibration System, a new instrument for measuring atmospheric and solar radiation characteristics (SERI)

Flat Plate Thin Films

Quadrupled the area to 4 cm^2 for thin-film GaAs cells while maintaining efficiency over 20% (Kopin)

Conducted reviews of Phase I accomplishments of Amorphous Silicon Research project; most milestones met. Awarded Phase II contracts (ARCO Solar, Solarex, Chronar, Energy Conversion Devices)

Demonstrated CdTe device stability for 3000 hours of testing under illumination at high temperature, 70°C (Ametek)

Developed new fabrication technique for window materials for copper indium gallium diselenide cells (Boeing)

Found promising high-band gap CdTe alloys for the top cell in a two-junction device (Jet Propulsion Laboratory, Georgia Tech, Ametek)

Made a 100-cm^2 polycrystalline silicon module with [illegible] efficiency (Astro Power)

Fabricated large-area back reflectors for a-Si submodules (Solarex)

Transferred laser scribing advances to production environment (Chronar)

Improved a-Si deposition rate (to 10 angstroms per second) while maintaining material quality [illegible] (Glasstech Solar)

Concentrator Cells

Delivered over 50 GaAs concentrator cells; highest efficiency 28% (Varian)

Developed small-area GaAs cell with high voltage for military applications (Sandia)

Flat Plate Crystalline Silicon

Completed the awards of university subcontracts under a joint Sandia/SERI solicitation (Sandia, SERI)

Achieved [illegible] efficiency in a 2" x 2" crystalline silicon cell that can be made more cheaply than most commercial cells today (University of New South Wales)

Module Research

Developed "Thin-Film Module Qualification Document" and "Thin-Film Module Reliability Plan" (SERI, Sandia, JPL, PV industry)

Assembled prototype and made initial tests of Sandia Baseline Module 3 (Sandia)

Began field testing of promising new array-tracking field controller (Sandia)

Began qualification testing of new [illegible] concentrator modules (Sandia)

Published "Qualification Tests for PV Concentrator Cell Assemblies and Modules" (Sandia, PV industry)

Completed qualification testing of all assemblies and modules for the ENTECH/3M/Austin project (Sandia)

Systems Research

Assisted U.S. Fish and Wildlife Service in establishing a PV energy system for Tern Island in the Pacific; system operating as planned; interested in more systems (Sandia)

Developed and published "Photovoltaics for Military Applications"; well-received by potential military users (Sandia)

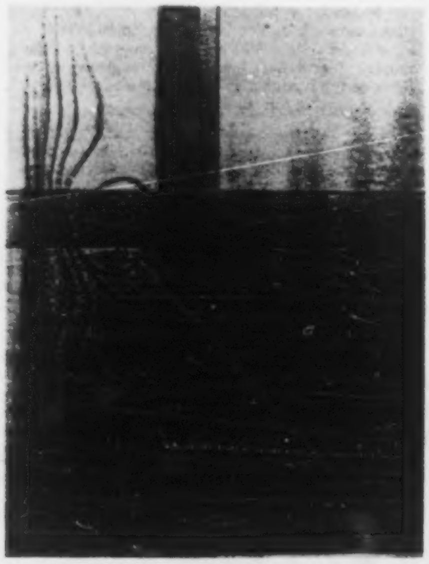
Continued work on Guatemala vaccine refrigeration project and advised UNICEF, USAID, Pan American Health Organization, and others on PV projects (Sandia)

Completed development of advanced power conditioning unit, with more than 95% dc-to-ac conversion efficiency and cost projections of $0.06 per watt (Sandia)

Performed detailed electrical analysis of fielded systems; developed substantial changes to PV section of National Electrical Code (Sandia)

Applications Experiments

Awarded contracts for four Emerging Technology modules for PVUSA. Installed data acquisition system; constructed instrumentation building (PG&E, DOE, Sandia, SERI)



SERI's convection heat-transfer laboratory showing ventilation jet in an indoor air quality test cell

Solar Energy Research Institute

Low-Temperature Heat and Mass Transfer Laboratory

Contact: Desikan Bharathan, Thermal Systems Research Branch

The laboratory is used to study and improve methods of transferring heat and mass under the small driving forces that often exist when the sun is the energy source. The driving force can be a temperature gradient or other intensive thermodynamic differential, such as a concentration gradient.

The current laboratory setup includes an enclosed test cell that can be operated at pressures ranging from two atmospheres to low vacuum. Warm and cold water circulate through the test cell, allowing efficient heat and mass transfer with a variety of exchangers. The test cell is fully instrumented to measure all process variables and is automated to efficiently acquire data.

The laboratory can be readily adapted to study and test other low-temperature heat and mass transfer processes, especially in advanced gas–liquid devices. Processes studied and tested include vacuum drying, material degradation caused by outgassing in vacuum environments, gas sorption and desorption from liquids, and other continuous and staged separation processes.

Desiccant Dehumidifiers

Solar Energy Research Institute

Solar Desiccant Cooling Laboratory

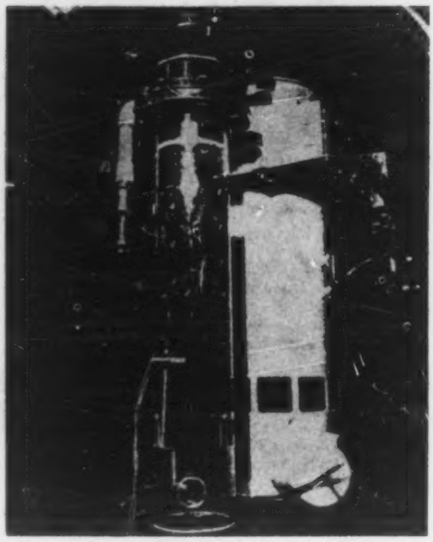
Contact: Ahmad Pesaran, Buildings Research Branch

The laboratory houses three facilities used to test materials, geometries, and components for desiccant dehumidifiers: sorption, single blow, and cyclic. All three provide controlled and conditioned process and regeneration air to test desiccant cooling systems.

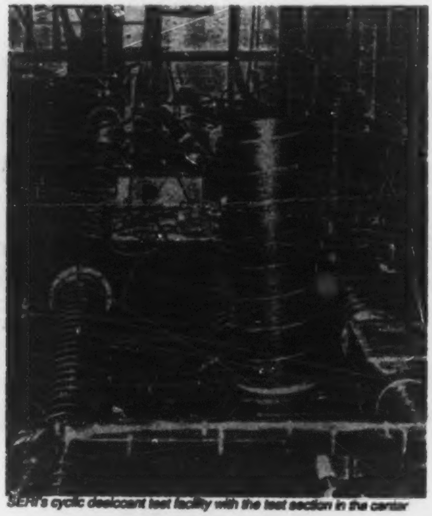
The sorption test facility measures the water equilibrium capacity and mass transfer rate of solid desiccant materials under isothermal conditions. These materials are exposed to process or regeneration air flow to attain dynamic equilibrium under a specific geometry.

The single-blow test facility generates data on transient heat and mass transfer and pressure drop for small-scale dehumidifiers with promising material and geometry combinations under adiabatic conditions. The momentum and heat and mass transfer characteristics can be measured to test the performance of different combinations of geometry and material.

The cyclic test facility is used to test advanced prototype desiccant dehumidifier components, such as



SERI's low-temperature test cell for testing heat and mass transfer showing direct-contact condensers



SERI's cyclic desiccant test facility with the test section in the center

a spirally wound wheel using silica gel with parallel-passage air flow. The test facility measures the performance of dehumidifier wheels under cyclic operation as a function of rotational speed, inlet air temperature and humidity, and air flow rates of both process and regeneration airstreams.

Apertures and Windows

Florida Solar Energy Center

Fenestration Research Facilities

Contact: Ross McCluney, Research and Development Division

Facilities and equipment for fenestration research include daylight availability measuring stations, a skylight testing station, a fast-response multichannel photometer, and solar calorimeters.

The daylight availability stations consist of instruments to measure and a computerized data acquisition system to analyze daylight. The Skylight Testing Station is used to test the optical properties of skylights and skylight wells. It is also used to calibrate light sensors and daylight measurements inside scale models of buildings.

The fast-response multichannel photometer can make rapid and repeated measurements of illuminance at eight locations by placing miniature light sensors inside small or full-scale models of buildings. The instrument is controlled by a computerized data acquisition system. The solar calorimeters measure the relative solar radiant heat gains through two different fenestration systems in simultaneous, side-by-side, outdoor tests in full sunlight.

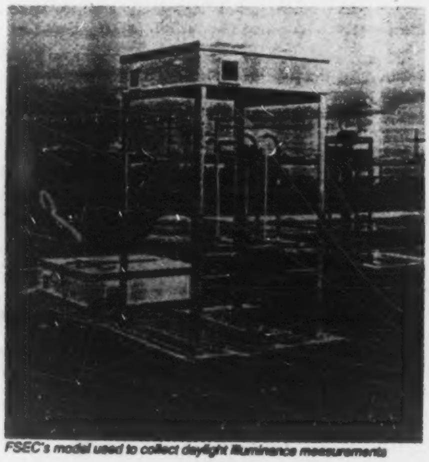
Lawrence Berkeley Laboratory

Solar-Optical Properties Laboratory

Contact: Stephen Selkowitz, Applied Science Division

The group has advanced facilities to conduct research on the optical and thermal properties of fenestration systems, shading systems, and building envelope systems. A large integrating sphere can measure the hemispherical transmittance of materials, components, and systems as a function of sun and sky conditions. The sphere can measure visible or solar transmittance for samples up to 2 ft by 2 ft. Typical uses for the integrater include measuring transmittance properties of skylight light wells; light guides; complex diffusing glazings with angle-dependent properties; and complex shading systems such as venetian blinds, fins, and honeycombs.

A luminance and radiance scanner for measuring bidirectional transmittance and reflectance of materials, components, and systems is also available for sample sizes up to 2 ft by 2 ft. The instrument measures the directional properties of visible (or radiant) flux transmitted (or reflected) through shading devices within 2-sr directions of emittance for any possible direction of uniform directional incident flux.



FSEC's model used to collect daylight illuminance measurements

SEIA

SOLAR ENERGY INDUSTRIES ASSOCIATION Suite 610 1730 North Lynn Street Arlington, Virginia 22209-2009 (703) 524-6100
FAX: (703) 527-2833

February 28, 1989

TO: Congressional Staff

FR: Scott Sklar

RE: Invitation to Seminars on Solar Breakdown and Destruction of Toxic and Hazardous Wastes

---

On Thursday, March 9th, you are invited to a briefing on the newest research breakthroughs of using concentrated sunlight to breakdown toxic and hazardous wastes. The brieifings will be conducted by experts from the Solar Energy Research Institute, Sandia National Laboratories, and the University of Dayton.

The briefings will run from 8:00 AM - 10:00 AM at the at the Holiday Inn Crowne Plaza near the Pentagon Subway stop. They have a shuttle bus from the subway or you can call them for directions at 892-4100.

This program is part of Soltech'89, a yearly event sponsored by the Solar Energy Industries Association, the U.S. Department of Energy, the Solar Energy Research Institute, Sandia National Laboratories, and others. SEIA will have a small trade show at the event and I hope you will stop by and I will be happy to take you around to the booths to review the new products and services provided by solar energy companies.

Finally, if you would like to attend SEIA's Annual Banquet on Tuesday, March 7th at 8:00 PM, or the reception earlier in the day from 5:00-7:00 PM, please contact Sandra Rupp at 524-6100. Thank you.

AGENDA
SOLAR THERMAL TECHNOLOGY PROGRAM ANNUAL R&D REVIEW

SESSION 2: NON-ELECTRIC R&D AND APPLICATIONS
(March 9, 1989, 8:00 a.m. - 11:40)

- SESSION 2 CO-CHAIRMEN: Bim Gupta (SERI) & John Thornton (SERI)

TECHNICAL PRESENTATIONS	SPEAKERS	TIME
(1) Opportunities for the Solar Processing of Toxic Wastes	*J. Thornton (SERI)*	*8:00 - 8:20*
(2) High Flux/High Temperature Solar Destruction of Hazardous Waste		
• *Laboratory Experiments*	*B. Dellinger (U of Dayton)*	*8:20 - 8:40*
• *Solar Furnace Experiments - I*	*G. Nix (SERI)*	*8:40 - 9:00*
• *High-Temperature Solar Destruction of Hazardous Wastes*	*J. Fish (SNLA)*	*9:00 - 9:20*
(3) Solar Detoxification of Organics in Water		
• *Research on Destruction of Organics in Dilute Aqueous Solutions*	*J. Webb (SERI)*	*9:20 - 9:40*
• *Engineering Studies of the Photocatalytic Destruction of Organics in Water*	*C. Tyner (SNLA)*	*9:40 - 10:00*
BREAK		*10:00 - 10:20*

SEIA

SOLAR ENERGY INDUSTRIES ASSOCIATION Suite 610 1730 North Lynn Street Arlington, Virginia 22209-2009 (703) 524-6100
FAX: (703) 527-2833

March 1, 1989

Contact: Scott Sklar
703-524-6100

SOLAR LEGISLATION PROMOTES NEW R&D, JOINT VENTURES & EXPORTS

WASHINGTON, D.C. - Bipartisan Members of Congress introduce landmark solar legislation in the House and Senate today in response to threats of international competition and global climate change. The Solar Energy Industries Association, the national trade organization of the photovoltaic and solar thermal manufacturers & component suppliers, hailed the legislation as "a bold legislative step with overwhelming benefits for the United States".

House Energy & Commerce Subcommittee Chairman Phil Sharp (D-IN) and Minority Chairman Carlos Moorehead (R-CA); and House Science, Space & Technology Subcommittee Chairwoman Marilyn Lloyd (D-TN) and Minority Chairman Sid Morrison (D-WA), introduced the "Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989". The companion bill was also introduced by Senator Wyche Fowler (D-GA) today and cosponsored by a majority of the Senate Energy & Natural Resources Committee. A summary of the bill is attached.

SEIA's Executive Director Scott Sklar praised the legislators for, "introducing landmark legislation which will maintain U.S. competitiveness overseas, provide jobs at home, and respond to the sobering effects of global climate change". Sklar stated further that the United States, in recent years, has been outspent by our international competitors in government sponsored R&D. The United States program has been cut by over 80 percent in the last eight years (see attached testimony).

Sklar said, "If Congress doesn't take the initiative, the United States will be forced to import the solar technology that we will need in the future which the United States developed originally at taxpayer expense -- and that would be tragic."

Solar-Energy Complex Hailed as Beacon for Utility Innovation

By Jay Mathews
Washington Post Staff Writer

KRAMER JUNCTION, Calif.—Almost no one noticed in 1984 when a few American and Israeli engineers opened a small solar-energy plant near this ramshackle crossroads in the Mojave Desert. Their effort was written off as another utopian venture certain to fail, and the group's next six solar plants also attracted little attention.

Now, however, as the turbines here with 194 megawatts of power driven from spreading ranks of trough-like parabolic mirrors and the company begins an unprecedented $1.2 billion expansion, major U.S. utility executives and World Bank economists are starting to hail the enterprise as an international phenomenon.

The Luz International Ltd. complex has become, with almost no notice, the largest solar-power facility ever built and the source of an estimated 90 percent of the world's electricity drawn from the sun's radiation.

At a time when some scientists are [illegible]ing economic and env[illegible] catastrophe from the "gr[illegible]ouse effect" caused in part by oil- and coal-fueled power plants, policymakers are thinking again about solar power and scrambling for information about Luz's rapid growth and technological innovations.

"We believe that they are far and away on the leading edge of this technology," said John [illegible], vice president of Potomac Capital Investment Corp., which owns a large share of the project as a subsidiary of Potomac Electric Power Co. in Washington.

"That is the world's most advanced effort to bring solar energy into large-scale production," said Scott Sklar, executive director of the Solar Energy Industries Association. He and other experts said the project shows that solar power can become a vital supplement to more traditional energy sources, particularly during peak daytime hours in hot, dry climates.

"We are seeing one company get a jump on an explosion," said Chris Jensen, a chemical engineer who came to work for Luz two years ago. "Anyone who thinks oil prices are going to stay down is naive. When they go up again, everybody is going to start talking favorably about solar, and we'll already be there."

Buttressed in its early years by federal and state tax incentives, favorable regulatory rules, a lucrative local power contract and the reputation of investor Arnold Goldman, one of its founders, Luz employs 700 people in California and Israel and recorded $185 million in revenue last year.

Although the tax incentives are almost gone in an era of budget deficits and cheap oil, a change in federal regulations has allowed the company to build five larger plants capable of tripling its generating capacity to almost 600 megawatts, enough for the residential needs of a city slightly bigger than Washington.

Robert San Martin, deputy assistant secretary for renewable energy at the Department of Energy, said he was particularly impressed by Luz's skill in finding a large market for its product. "It's very clear that they have been a substantial success story," he said.

Company officials and investors said the new plants' larger size and several technical improvements would decrease the crucial cost of solar power to about eight cents per kilowatt hour. That is less than the cost of power from new nuclear plants and closer to the average cost of electricity, about six cents per kilowatt hour, than solar-power engineers have ever achieved.

At the same time, company officials and the Solar Energy Industries Association, based in Arlington, Va., are calling for a reversal of declining government support of research and development of both solar-thermal energy and other major solar technologies, particularly the direct sunlight-to-electricity conversion called photovoltaics, which runs solar-powered watches and calculators.

Both solar thermal and photovoltaics, the association said in two reports last November, can with government assistance strengthen "the U.S. competitive edge, provide reliable domestic energy, lower environmental degradation, strengthen national security, lessen Third World debt and aid the U.S. balance of trade."

Luz was founded in 1979 by Goldman, an American engineer with a reputation as a dreamy visionary and clever businessman, and Patrick François, a French financier. They named the company Luz after the biblical site of Jacob's ladder, the place where the Hebrew patriarch dreamed of angels moving between heaven and Earth. Luz also is the Spanish word for light.

Goldman's reputation as the man who designed one of the first word processors and who sold his successful Lexitron Corp. to Raytheon helped win initial funding for his solar-energy scheme.

The company began research and development in Israel, where Goldman and François also have citizenship. In a telephone interview from Jerusalem, Goldman noted that linear solar-thermal technology is "quite old" but that research at places such as Sandia National Laboratory in New Mexico and his own experiments gave it "an efficiency that it had never attained before."

The Luz method uses long troughs of curved mirrors, guided by computers, to heat synthetic oil passing through vacuum-sealed tubes to 735 degrees Fahrenheit. The oil in turn heats water to produce steam and run an electric turbine.

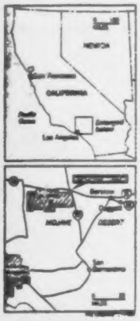
They set up the first small, 14-megawatt plant in Daggett, 30 miles east of here, added a second, then built their third through seventh plants in this tiny road stop about 140 miles northeast of Los Angeles near Edwards Air Force Base. Kramer Junction comprises little more than a few gasoline stations and some roadside eateries such as "The Astro Burger," but its light blue desert sky offers what assistant general counsel Paul [illegible] calls "clean sun," a dependable source of solar radiation usually untainted by smog, clouds or rain.

Southern California Edison Co., which buys Luz-generated power, is required by federal law to purchase electricity from qualified small suppliers. But the huge utility, impressed by Luz's performance, has given the solar company stable and profitable 30-year power contracts.

On hot summer afternoons when demand from millions of Los Angeles air conditioners peaks, the sun beating down on Kramer Junction generates maximum solar power. "It's almost poetic, it's such a perfect match between solar and what Edison wants," Jensen said.

In the winter, when the sun's rays are weaker or when Edison needs extra power at night, such as during California's recent cold snap, Luz uses a small natural-gas boiler to supplement or replace solar power. The plants qualify for exemption from expensive federal paperwork requirements if no more than 25 percent of their power each year comes from such nonrenewable sources as gas.

The computer-guided parabolic mirrors at the Luz solar energy complex heat synthetic oil, which warms water to produce steam that runs an electric turbine.



Luz is negotiating new contracts with San Diego Gas and Electric and exploring sites for plants in Arizona, New Mexico, Brazil and India. Company officials contend that their power costs would look even cheaper if governments compared the costs not only of building a coal or nuclear plant but also of digging up fragile landscape for more coal or uranium and polluting the air and water.

Building a solar plant, Luz executives note, also is much quicker, requiring as few as 10 months after contract signing, compared with five to 10 years for many fossil- and nuclear-fuel plants.

Workers who arrived at Kramer Junction when little more than sagebrush dotted the landscape shake their heads at the new office building, the acres of mirrors and the intricate maze of heat-transfer pipes spreading over the desert. Jensen smiles and points to three thick cables supported by wooden poles running past The Astro Burger toward the unseen cities to the south.

Several Luz executives and investors recently addressed a Washington audience at the invitation of the World Bank, a welcome sign of acceptance to many workers here. "They used to say, 'You'll never do it,'" Jensen said. "Now they say, 'You did it. We're interested.'"

Mrs. LLOYD. Thank you, Mr. Sklar.

When you go back to the Appropriations Committee, you tell them that we did pass our authorization bill last year. The Senate didn't do as well as we did, but we got ours out.

Mr. SKLAR. I appreciate that.

Mrs. LLOYD. Mr. Hutchison.

STATEMENT OF JOSEPH HUTCHISON, PRESIDENT, SOLAR KINETICS.

Mr. HUTCHISON. Thank you, Madam Chairman. I appreciate the opportunity to be here today and present my industry's views on the fiscal 1990 R&D budget for solar thermal research.

Mrs. LLOYD. We are happy to have you.

Mr. HUTCHISON. I'm the Chairman of the Solar Thermal Power Division. We are a group of small and large companies and utilities who believe that in the years to come, the mid-90's, we can make a significant contribution to the electric grid of our nation. We believe the demand will be there and we know we can make a significant contribution, but we need your help, and we need your help for several years.

Our industry uses three basic kinds of concentrators, as you know, parabolic troughs, parabolic dishes and heliostats, and we sort of break up the technology by concentrator type for clarity.

As with the previous speakers, we are also increasingly aware of such issues as the greenhouse effect, ozone layer depletion, acid rain and nuclear waste disposal. We believe that solar thermal power can contribute in an environmentally benign way to this grid requirement.

The last time I spoke to this group, our industry—since that time our industry has continued to make progress in meeting our technical goals.

The second generation of heliostats has been installed at Sandia and are operating according to specifications and have met the promised cost reduction goals.

The solar thermal initiative in the stretched-membrane dish technology has continued as well, and we have made a number of stretched-membrane dish optical element which have exceeded the DOE optical goals. This fiscal year we will build an intermediate sized stretched-membrane dish, and in fiscal year 90 we expect to build a full-sized stretched-membrane dish; couple that dish to a Stirling cycle engine at Sandia National Labs and produce electricity at the efficiency rate of 30 percent.

We have also, as Mr. Sklar has indicated, achieved 200 megawatts of capacity in California. That technology is based on the parabolic trough technology, which was developed at Sandia and SERI with DOE funding, and I was a part of that program in the early and mid-70's.

We believe that within five years and with adequate DOE support the commercial sector can complete development and commercialize the dish Stirling technology and the central receiver technology using stretched-membrane mirror technology for both applications.

During the past year scientists operating within the program have been looking for innovative and unique uses for stretched-membrane mirror technology, and they have discovered that organic chemicals when exposed to concentrated sunlight can be destroyed or reformed to more usable or desirable materials.

There are two basic approaches to this. You deal with concentrated organic chemicals. We may call those toxic wastes, PCBs or, if you will, pure chemicals that are undesirable or a very dilute contamination of water, particularly in this case groundwater which may have industrial solvents in it and make it not useful for irrigation or other human uses.

We can use a dish technology at very high concentration ratios with a catalyst, particularly rhodium. We can pass these organic solvents over this catalyst in the concentrated sunlight and we can destroy them entirely to EPA standards.

We can take contaminated groundwater and expose that to low concentrations of solar energy using heliostats and destroy these contaminants. They are typically chlorinated hydrocarbons from cleaning or paint solvents or the like. We can meet EPA standards and we can in fact exceed EPA standards, rather than simple incineration, which is the current method, which is quite expensive and produces effluents which have to be dealt with and also product carbon dioxide.

Of particular interest, the catalyst in the water cleanup method is simply titanium dioxide, which is white paint pigment, very benign.

We believe that this water cleanup solar concept can be used in a meaningful way in the DOE manufacturing site project. We believe that this technology is not long term and is not high risk. It's very simple in its approach, and therefore we think we should go ahead with the development of the concept and it may very well be useful at some of these sites.

As I have said, we have three major thrusts, the dish Stirling, the central receiver and the new concept called solar chemistry.

The first two need to be finished. The first two jobs are not completed. Our budget continues to be reduced, we continue to reduce our scopes of work and we are simply to the point, as Scott said, that continued reductions will imperil both of those programs.

With the addition of the new solar chemistry program, it places even tougher burdens on us as a community. We see this as a great opportunity and we are desirous of working on it, but we must have additional funds in order to do so. We have sustained budget reductions far in excess of other programs and we are simply at a critical point at this point in time.

We believe that our industry has multiple benefits and can produce manufacturing jobs, the kind of jobs that we need, and because our products are material intensive, we can also through this solar chemistry technology have an impact on the ever-growing stockpiles of unwanted chemicals.

For example, in last month's issue of American Scientist Magazine, a publication of Theta Zi Scientific Society, there as an excellent article on the chlorinated fluorinated hydrocarbon impact on ozone, and it gave us, if not a lay explanation, a reasonable explanation that a technical person could understand, and for the first time I grasped the real problem.

One molecule of these fluorinated hydrocarbons can destroy over 80 molecules of ozone on its way to UV degradation. Our nation could institute a policy where unwanted refrigeration units, old cars and refrigerators must go by a site where the freon is removed, and the freon could be reduced to table salt or inorganic chemicals that are not toxic and not poisonous. This would be one of the potentials for the new solar chemistry concept.

We in the Solar Thermal Power Division of the Solar Energy Industries Association recommend a stable level of funding of approximately $20 million for the next several years in order to get the job done. We believe the program goals can be achieved and we can deliver significant quantities of electricity in the mid-90's. We believe we can see the beginning of this new solar chemistry industry.

We cannot do this with a $13 million budget, which is a 15 percent reduction over a $15 million budget, which was untenable. We actually operated at $18 million last year because we had passbacks. So we're looking at a 40 percent reduction and not a 15 percent.

We are delivering the technology we promised. We have done everything I promised you we would do last year during this last 12 months.

We hope you will consider these recommendations, and I look forward to any questions you may have.

[The prepared statement of Mr. Hutchison follows:]

SEIA

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FAX (703) 527-2833

STATEMENT OF THE SOLAR THERMAL POWER DIVISION OF THE SOLAR ENERGY INDUSTRIES ASSOCIATION ON THE U.S. DEPARTMENT OF ENERGY FISCAL YEAR 1990 BUDGET

BEFORE THE ENERGY AND WATER DEVELOPMENT
SUBCOMMITTEE ON APPROPRIATIONS

CONGRESS OF THE UNITED STATES
HOUSE OF REPRESENTATIVES

Prepared by
Joseph Hutchison, Chairman

2 MARCH 1989

Madam Chairman, Members of the Committee, I am appreciative of the opportunity to offer my industries views on the FY'90 budget request of the Department of Energy for solar thermal research and development.

My name is Gus Hutchison, I am the President of Solar Kinetics, Inc. of Dallas, Texas and I am also Chairman of the Solar Energy Industries Association (SEIA) Solar Thermal Power Division. We are a trade organization made up of large and small companies involved in the development of solar thermal power (electricity) technology. Our technologies include several methods to concentrate the sunlight. The three basic concentrator types are parabolic trough, parabolic dish, and central receiver (heliostat).

I am here today to reaffirm our commitment to the production of significant amounts of electricity for the nation's grid without the use of fuels of any type. We sincerely believe and are strongly dedicated to the implementation of these concepts in the mid to late 1990's. We believe it can be done, we know it must be done, and we recognize that we must have your help in order to bring this much needed technology to the marketplace.

We are all becoming increasingly aware of such issues as the greenhouse effect, ozone layer depletion, and acid rain. We continue to be aware of the problems associated with nuclear waste disposal. While there is a lot of work left to be done, solar thermal power can contribute, in an environmentally benign way, to the energy needs of our nation.

Since I last spoke to this group, our industry has continued to make progress to meet our technical goals. The second generation of stretched-membrane heliostat prototypes have been fabricated and installed. These units are performing according to specifications and show significant cost reduction. Stretched-membrane dish technology continues to progress with prototype mirrors being made well in excess of the optical goal set by the Department of Energy. An intermediate size stretched-membrane dish is planned for the next fiscal year with a full-size unit to be built and installed at Sandia National Laboratories during fiscal 1990. This unit will be coupled to a state of the art Stirling cycle engine and will produce electricity in excess of 30% efficiency.

Nearly 200 megawatts of solar thermal power generation capability is currently supplying electricity in California. These projects utilize parabolic trough technology, which was developed under the DOE R&D program. The projects were made cost effective through tax incentives which are due to expire December 31, 1989. It is clear, however, that when solar thermal power generation becomes more cost competitive, significant large-scale implementation will be a reality.

Parabolic troughs are technically preferred for low temperature applications such as, steam for industry. When utilized for generation of electricity, they are not as efficient as parabolic dishes or central receivers. These latter technologies are appropriate for electric grid power, but still require additional development in order to be competitive with fossil fuel technologies.

We, in the Solar Thermal Power Division, still believe that within five years and with adequate DOE support the commercial sector can complete development of and commercialize these two basic solar thermal power technologies. The Dish Stirling Electric concept utilizing the stretched-membrane dish promises high efficiencies and low costs for central power plant application as well as distributed applications. Central Receiver or Power Tower technology will utilize the stretched-membrane heliostat mirror concept for production of electric power in 50 megawatt blocks.

During the past year, those scientists operating within the DOE funded program have discovered some unique uses for the new stretched-membrane mirror technologies. It has been learned that organic chemicals, when exposed to concentrated sunlight and the appropriate catalyst, can be either destroyed or reformed into more desirable chemicals. This has given rise to a new initiative, within the program, called solar chemistry.

There are two basic approaches, one utilizing very concentrated sunlight and high concentrations of toxic chemicals, while the second uses lower solar concentration on very dilute contaminants. The former concept utilizing parabolic dishes and a catalytic reactor promises the destruction of highly concentrated organic chemicals such as chlorinated hydrocarbons and PCB's . The Central Receiver technology, using heliostats, provides a means for purifying contaminated ground water in massive quantities with reasonable size solar arrays.

It has been demonstrated that chlorinated hydrocarbons, when exposed to the solar concentration of a parabolic dish within a quartz vessel containing a rhodium catalyst, can be reduced to chemicals as simple as water and table salt. This photodestruction process exceeds EPA requirements, while simple incineration results in unacceptably high air pollution which must be further controlled.

It has also been demonstrated that heliostats concentrating sunlight onto a simple aluminum plate, over which contaminated water is cascading, can eliminate many common organic contaminants such as chlorinated hydrocarbons, paint solvents, etc. In this case, the very cheap and common catalyst is titanium dioxide (white paint pigment).

It is a well known fact that the ground water around many of our Department of Defense nuclear manufacturing sites is contaminated. Those contaminants are not limited to radioactive materials. In fact, the highest percentage of contamination is due to industrial solvents. This solar technology can contribute to the clean-up project and may be able to achieve results unattainable through other methods.

This new solar technology for ground water clean-up is not high risk, long-term research and development. It is near-term technology and should be supported in view of the DOD site clean-up program.

The program now has three major technical thrusts and they are: the Dish Stirling concept, the Central Receiver concept, and Solar Chemistry. The first two concepts can be within a few years of commercialization, but require sustained R&D support for completion. The new Solar Chemistry technology is very deserving of support, but cannot be funded without diminishment in the first two essential programs unless additional funding is committed. The Solar Thermal Power Division strongly recommends a $20 million R&D budget for fiscal 1990. This is $2 million less than requested last year. At this level, all three programs can move forward in a well rounded and balanced way. Such a program must include development of optical materials, receivers, storage systems, and applications studies. We strongly endorse the DOE Five Year Plan as a means to achieve the important goals that are in sight. We also strongly endorse the roles played by Sandia National Laboratories to develop the solar thermal hardware and by the Solar Energy Research Institute to research materials and new concepts. We believe that both institutions should continue, as in the past, to support industries efforts to further these important technologies.

Our technology program has sustained budget reductions, far in excess of most others. We are at a critical point and further reductions will result in the untimely demise of both solar thermal power generation technology development programs. The addition of the new important solar chemistry program, without additional funding, will also result in an unsatisfactory result.

There are multiple benefits to be realized as these technologies reach the marketplace. Additional electric generating capacity will be required in the years to come and solar can provide that capacity in a clean and environmentally safe way. This technology will be a step in the right direction towards the elimination of the greenhouse effect. Solar chemistry can help alleviate the ever growing stockpiles of unwanted toxic chemicals and can provide a means of destroying these chemicals without further pollution. Current incineration technologies are very costly and still produce high quantities of carbon dioxide and some other pollutants.

The solar collector industry will be a very material intensive, manufacturing industry and will produce new jobs. These jobs will be manufacturing in nature, the type of jobs sorely needed by this nation. As a result of the DOE program and industry cost share since 1975, our country still clings to the lead in solar thermal technology. Further budget reductions will be read as further de-emphasis and our foreign competitors will seize the opportunity. We have the chance to export this technology and reduce the trade deficit or; once again, we can do most of the work and through lack of resolve watch our foreign competitors enjoy the benefits.

We, in the Solar Thermal Power Division of the Solar Energy Industries Association, recommend a stable level of funding of approximately $20 million for the next several years. We believe that the program goals can still be achieved with industry cost share, if this level is maintained. The funding request of $13 million is 15% below the FY'89 level of $15 million and would imperil the future of the program. I have included a copy of the industries' recommendation for the DOE fiscal year 1990 Solar Thermal Research Budget. We are delivering the technology we have promised. We are simply here asking for your continued support so that we can finish the job.

We ask you to consider the budget recommendations we have offered and we are ready to answer any questions you may have.

SOLAR THERMAL ENERGY PROGRAM
US-DOE BUDGET SUMMARY

	FY'86	FY'87	FY'88	FY'89	FY'90 INDUSTRY RECOMMENDATIONS
1. Collection Technology Research	9.7	9.0	10.0	6.6	10.3
a) Optical materials	1.8	1.4	1.5	3.0	2.3
b) Concentrators	4.0	4.2	4.4	2.6	4.5
c) Receiver	3.9	3.4	4.1	1.0	3.5
2. Energy Conversion Technology and Research	4.7	5.1	2.5	5.2	3.2
a) Heat engines	2.7	1.9	1.5	4.0	1.5
b) Direct conversion	0.8	1.2	0.8	1.0	1.5
c) Transport and storage	1.2	2.0	0.2	0.2	0.2
3. Central Receiver Research	5.5	5.5	2.7	1.4	3.6
a) Innovative concepts					
b) Balance of plant					
c) Utility studies					
d) Cost-shared programs					
4. Distributed Receiver Research	5.3	3.2	1.7	1.5	2.9
a) Innovative concepts					
b) System experiences					
c) Cost-shared programs					
5. Capital Equipment	0.3	0.0	0.1	0.3	0.2
TOTALS	$25.5	$22.9	$17.0	$15.0	$20.2

Mrs. Lloyd. Thank you very much for your testimony. I'm very interested in your solar chemistry in this case. It sounds exciting and the prospects are certainly good for a good industry.

Mr. Hutchison. Right. We are all very excited about that.

Mrs. Lloyd. Dr. Hubbard, it's very good to see you back today.

STATEMENT OF DR. HAROLD M. HUBBARD, DIRECTOR, SOLAR ENERGY RESEARCH INSTITUTE

Dr. Hubbard. Well, Madam Chairman, let me say it's very good to see you back today. I think there was a time last year or the year before when you threatened not to do that.

Mrs. Lloyd. I fooled you, didn't I? [Laughter.]

Dr. Hubbard. That's right, you did. So let me say we are all glad to see you back.

Mrs. Lloyd. Thank you.

Dr. Hubbard. The cast of characters is kind of familiar, and sometimes in talking to you and Mr. Morrison I sort of feel like I'm simply being repetitive in talking to the choir.

I submitted to you for the record a rather long statement which tries to summarize the general situation with respect to renewable energy and the progress that has been made.

I will move through the major points of that rather quickly and try to amplify a couple of the points made, and then I would rather reply to your questions than to spend a lot of time talking at you on mostly things that you already know.

But the main points in that testimony are simply that renewable energy is big today, and you know that of course.

About nine percent of our total energy supply now comes from renewables, and most of that from what I tend to call maturing technologies, namely, combustible biomass, hydropower, et cetera, but the emerging technologies are beginning to make substantial contributions also, and as we look down the track we can see future technologies are coming along relatively rapidly. We expect that that growth will continue.

Now there is a misprint that I'm unhappy about in the testimony that I submitted to you. That statement earlier in there that there was a some 440 percent growth in renewables from 1974 to the current time is wrong. The base number rather than 1.5 should have been something like 4.5. So the actual increase is more like 150 percent.

I was over at the Department this morning and people were massaging numbers as usual, and I ran across a number I hadn't seen before, and that is that the value of renewable technologies used every day in this country translated into terms of equivalent barrels of oil at $18 a barrel is a little bit over $50 million, or roughly $55 million.

Now it so happens that the annual budget for SERI and solar research is somewhat under $50 million. So in a sense we recover the total SERI annual budget every day in this country because of the initial renewable energy, and that's a pretty good return, although I don't think that SERI can claim credit for all of that.

Mrs. Lloyd. Why don't you claim credit for it. [Laughter.]

Mr. **Hubbard**. Well, I try to be both modest and accurate, you see, in spite of the temptation sometimes to the contrary. [Laughter.]

If you like to look at numbers, and everybody does, the Department recently made an estimate of the accessible energy reserves in this country. Now energy reserves are interesting. There are total reserves, accessible reserves, economic reserves, et cetera. But in that analysis approximately 90 percent of the accessible energy reserves in this country are renewable energy reserves. So it is by far the biggest energy reserve or by far the biggest physical resource that we have and we have just barely tapped it, and we are not investing a lot in tapping it either, and I'm not sure that makes a lot of sense.

We use about 140 billion gallons of gasoline in this country now per year. If you look at the biomass reserve, one could conceivably get to somewhere between 130 and 260 billion gallons of ethanol in gasoline equivalent per year. It could supply the whole transportation industry. I'm not saying it should because I don't want us to wreck the economy like Mr. Smith said, and it probably would if we really pushed for that, but the potential is there and over time we will learn how to do that economically.

The research is making good progress. Some of the graphs we have shown you before indicate that. That's true in photovoltaics, it's true in biomass, it's true in wind and it's even true in oceans, and there are new applications coming along, some of which Gus has already talked about.

I picked up a piece of paper as I was leaving the office because people are always asking me about breakthroughs, and it has to do with the issue of using solar thermal radiation for the decomposition of toxic materials. And the scientific question in that that has always been a problem, and I looked at it in DuPont's laboratories 30-odd years, was when you're using concentrated sunlight to catalyze reactions, how can you distinguish between what's thermal and what's quantum, and some data turned up yesterday that indicated in the decomposition of certain toxic materials we can improve the efficiency by a factor of about 10,000 if we use concentrated sunlight and if we use the quantum effect as well as the thermal effect, and that's pretty impressive scientifically and every other way.

If you look at the reasons for using solar energy, and I don't want to hang it on the greenhouse effect. There is a lot of discussion about that, and it enhances the reasons for doing solar energy research, but there are a whole collection of reasons why it makes sense.

The first of course is national energy security, and you've heard this so many times you must be tired of it, but what can you say about renewable energy. It is domestic and we've got it. It is versatile because you can do electricity, you do transportation fuels, you can heat houses, you can run processes, and it is non-depletable. So that's the basic reason why we need to have this science base and we need to have the industry base, but you get more than that for it.

It helps our economy. There are a set of emerging technologies that are now establishing substantial international markets and we should be addressing those international markets. It obviously helps on the balance of payments with respect to imports and it creates domestic jobs.

The environmental issue is obviously important, and the greenhouse effect we have already talked about. I wish Mr. Smith were still here, because the greenhouse effect is real. If it were not, neither Mr. Smith nor I nor any of us would be here because the earth would be uninhabitable. So it's not a question of whether the greenhouse effect is real or not. It's a question of the buildup of greenhouse gases. That's clearly real also. We know enough about the chemistry and the physics of the atmosphere to be able to say that as these gases build up, gas that trap infrared radiation and reflect it back into the earth, sooner or later it will have an impact on the earth's climate. What's debatable is whether there is a detectable warming trend or not.

Something on the order of 90 percent of the scientific community, and maybe 95 by this time, believe that that effect is detectable, and we work a lot with the National Center for Atmospheric Research, which is up the road from us, and they probably know more about climatic modeling and that sort of thing than any institution in the world, and you won't find anybody at NCAR who does not believe that the global warming effect is detectable.

Now it gets more problematical as you try to translate that into what the specific effect on the climate might be. It would be proper and most of the scientific community would not say that last year's drought was relatable back to the build up of greenhouse gases, although it's conceivable that it might be.

There is one other thing I would like to point out, and that is scientifically renewable energy research is not trivial. It addresses some of the most important and basic scientific phenomena any place. So if you look at what goes on at SERI or what goes on in the hydrogen program at Texas A&M and other places, there are very profound scientific questions underlying that. The question of really the whole matter of photosynthesis is basic to that. There is no more fundamental scientific question any place than that. So we produce good science as well.

The problem, as everybody has indicated already, is that to produce good science and to do good things for the environmental, to help the economy and to make sure that we have national energy security, we've got to spend some money, and we have been, but as you look at that trend chart over there, it gives you pause to wonder.

I mean suppose you were the Arco Board of Directors, and with characteristic American attention to the bottom line on a three-year time span, they don't see any particular return from photovoltaics in that time span, and they look at the government willingness to share the risk by funding the research and they see that going down. Then where does that extrapolate to zero, another three years out or so.

They see the fact that the principal research facility at SERI has never been funded, and that's more than a problem to SERI in terms of efficiency and in terms of our ability to work. It's a symbol of a commitment by the government to what should be a relatively long-term program. So when you look at that they say, gee, if we are not going to get any help, why should we invest the funds. And when American investors and entrepreneurs look at buying Arco Solar, which would probably be a pretty good buy, the same kinds of questions arise in their mind. So there is a real problem with respect to consistent and adequate funding that concerns all of us.

And I don't understand that particularly well either, particularly at this point in time because we have a new Administration, the budget you have in front of you is basically an OMB budget that comes from the past Administration, and it would begin to sound like we have a different set of priorities.

President Bush is very strongly interested in environmental issues and has said so. You cannot talk about environmental issues without talking about energy.

Admiral Watkins I think, who was confirmed yesterday by the Senate by 99 to zero, in his statement has indicated that renewable energy and environmental concerns are a matter that he intends to pay attention to.

And being something of a C-SPAN junkie, I listened to Mr. Darman in front of Senator Byrd the other day, and Mr. Darman said in putting the budget in front of you we are looking at those things which we absolutely have to do, such as pay the interest on the national debt, those things which are supportive of society today that are important, the Social Security issues, the need for enhanced education, et cetera, and then those things which ensure that we have a livable future in this country and an economically secure future in this country, and he talked about technological competitiveness, he talked about good science and he talked about environmental concerns. He didn't talk about energy security, but one would hope that he would have.

So if you look at and screen what you've got for the investment in renewable energy research back against that set of criteria that Mr. Darman laid out, you have to conclude that it is a pretty good investment.

Under those circumstances I should think one would say since the new Administration and the new Congress has not had a chance to clearly delineate what they mean as they set those priorities out, it would make sense to say let's maintain the expertise that we have, let's stabilize those centers of excellence and let's keep some continuity in the program, and then as those priorities emerge one can look at the program's relevance to those priorities, and when one does that I think Scott Sklar would be back here next time and I would probably be seconding or arguing for an increase in the budget rather than stability, but I think it certainly makes sense to argue for stability today.

Thank you.

[The prepared statement of Dr. Hubbard follows:]

Testimony of Dr. H.M. Hubbard

Director
Solar Energy Research Institute

Before the
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Abstract

In this testimony I address several significant questions regarding renewable energy, including how big its contributions are, how large the contributions can be, how much progress the renewable technologies have made, how the renewable energy technologies can help America, and how renewable energy R&D depends upon continued support. Specifically, my testimony shows that:

- Presently the renewable energy technologies provide America with 9% of her total energy needs, more than that of even nuclear energy;
- The contribution of renewable energy to America's energy supply has grown by 440% in 13 years, to 6.6 quads;
- The potential of renewable energy is enormous and could supply the United States with as much as 20% of her energy needs by the year 2010, and increasingly more thereafter;
- The renewable resource is unbelievably vast;
- That all of the renewable energy technologies improved rapidly under the national R&D program, with systems becoming increasingly reliable, more efficient, and longer lived, and with the cost of energy from most of the technologies decreasing by at least an order of magnitude;
- The renewable energy technologies will aid our nation's energy security by helping to light, heat, and cool our buildings, by supplying us with transportation fuels, and by assisting us in meeting our growing demand for electricity;
- The renewable energy technologies will help our economy by enabling us to better compete in international markets, improving our balance of payments, and creating jobs;
- The renewable energy technologies are the best energy alternative for protecting our environment, by alleviating the problem with acid rain, replacing CFCs in refrigerants, and mitigating global warming; and
- The renewable energy technologies require continued and consistent R&D support if they are to help America secure her energy future, improve our technological competitiveness, assist with our balance of payments, and assure us the ability to develop strategic responses to concerns about global warming and other environmental issues.

Renewable Energy is Big Today

Last year, the United States derived nearly 9% of its energy from renewable energy sources.

Last year, the United States derived nearly 9% of its energy from renewable sources, a total of 6.6 quads of energy. (A quad is one quadrillion, or 10^{15}, Btus of energy.) This is enough energy to run America for a month. In terms of oil, the annual amount of energy from renewable sources is equal to 1 billion, 135 million barrels, two-thirds of the amount of crude oil that the United States imported in 1987. Figured at $18 a barrel, the energy from renewables is worth over $20 billion a year.

Much of the present contribution of renewable sources comes from two mature technologies: the combustion of wood and hydroelectric power. The combustion of wood and wood wastes produced 3 quads of energy in 1987, an energy equivalent to 515 million barrels of oil. And hydroelectric systems supply America with more than 80 billion watts of power, 13% of all our electricity.

Renewable sources provided America with more energy than synfuels, fuel cells, clean coal, or even nuclear power.

These are large and impressive numbers. How large becomes more apparent when considered in relation to how much energy our nation gains from other important sources. Nuclear energy, for example, provides America with three-fourths the amount that renewable energy does, 4.9 quads. Also, renewable sources provide far more energy than synfuels, fuel cells, or clean coal.

One strength of renewable energy is that it relies on a wide variety of available natural resources: the sun, wind, oceans, plants, wastes, and falling water. A large and growing set of technologies is used to exploit these resources. Some of these are mature technologies, while others are now emerging from the DOE's Energy R&D Program as the energy technologies that will help America secure its energy future while protecting its environment.

An unexpectedly large amount of renewable energy has been developed under the Public Utilities Regulatory Policies Act (PURPA). Until the passage of PURPA in 1978, the great majority of electric capacity in America was produced by electric utilities. Since then, however, an increasingly significant amount of new capacity has been added by independent producers — more than 25 billion watts of capacity, all told. Renewable energy technologies have provided 40% of this capacity, or 10 billion watts. This amount, which is 2-1/2 times as great as originally projected, suggests several things. First, renewable energy can and will help America meet its needs for new generating capacity. Second, since the installed capacity represents private investment of between $15 and $20 billion, it is clear that renewable technologies for electricity are a sound investment. And third, since independent producers installed more capacity last year than utilities, recent trends indicate that renewable energy may well provide more than 25% of all new capacity in the immediate future, and even more later.

Contribution from Renewable Energy Has Grown Rapidly

From 1974 to 1987, the contribution from renewable energy technologies grew from 1.5 quads to 6.6 quads — 440% in 13 years.

From 1974 to 1987, the contribution from renewable energy technologies grew from 1.5 quads to 6.6 quads — 440% in 13 years. This is a remarkable feat, especially since in that same time frame the United States increased its total yearly energy consumption by only 1.5 quads. The increase in renewable energy, in other words, covered the total increase in U.S. energy consumption by greater than 2-1/2 times.

While the bulk of this additional energy came from the mature technologies of hydroelectric power and the combustion of wood, with Congressional support and sound DOE management some of the more dramatic advances occurred in the emerging technologies of geothermal energy, biofuels, wind, solar thermal, and photovoltaics.

Geothermal energy, electric power from the energy of the earth's internal heat, has grown even more dramatically than that from municipal solid wastes — from 12 million watts of electricity in 1960 to nearly 3 billion watts in 1987. This is a growth of 250 fold.

Ethanol production from biomass has risen to more than 800 million gallons per year.

Biofuels is short-hand terminology for the production of energy (mostly liquid and gaseous fuels) from plants and waste. Through the biotechnologies we can make ethanol, methanol, crude oil, and methane to heat our buildings, provide electricity, and to supply liquid fuels for transportation. An example of the increasing importance of biofuels is the dramatic growth in ethanol production, which has risen to more than 800 million gallons a year. Another example is that an increasing number of cities are starting to turn their wastes into electricity — municipal solid wastes are now used to produce more than 1 billion watts of electric power.

Wind energy, where the mechanical energy of wind is transformed into electrical energy, has grown in like measure. Just a decade ago, electricity produced from wind was a curiosity. Today, it is big business, with about 2 billion watts of wind-electric capacity installed in California alone. In 1987, these wind machines generated more than 1.8 billion kilowatt-hours of energy.

Solar thermal technology, where the sun's rays are focused to produce large amounts of heat or electricity, also grew rapidly. Barely in existence a little more than a decade ago, this technology has progressed to where it now provides more than 200 million watts of electrical capacity. Of these, 195 million watts are installed in the Luz plant in the Southern California desert, where the plan is to increase the capacity to 575 million watts in the next few years.

Today, the U.S. produces more than 10 million watts of photovoltaic modules each year.

Photovoltaics (PV), the use of solid-state devices to generate electricity directly from sunlight, has also scored its share of remarkable successes. In the mid 1970s, PV was an expensive and exotic technology whose only application was to power satellites in space. Intense research and development has brought this incredible technology "down to earth" where it has found applications that range from running wrist watches, to providing electricity for homes, to powering entire communities. Today, the U.S. produces more than 10 million watts of photovoltaic modules per year. Thousands of systems, ranging in size from milliwatts to megawatts, have been installed throughout the world. And the annual world-wide market is greater than $200 million and growing.

The Contribution from Renewable Energy Will Continue to Grow

The Office of Technology Policy projects that by the year 2010 renewable energy technologies will supply the United States with nearly twice as much energy as they do today.

The DOE Office of Technology Policy (OTP) projects that by the year 2010 the renewable energy technologies will supply the United States with nearly twice as much energy as they do today — almost 13 quads. The OTP figures also assumed a growth in total U.S. consumption to 108 quads. Under OTP's analysis, renewable energy technologies will supply 12% of America's total energy.

SERI analyses indicate that renewable energy technologies could provide our nation with as much as 20% of its energy by the year 2010.

Using OTP figures, SERI did its own analyses. One analysis assumed the government would provide leadership on such things as reducing greenhouse gases, and would thus provide incentives for the increased use of conservation and renewables. This analysis indicated that renewable energy technologies could supply the U.S. with as much as 18 quads of energy by the year 2010. Since this analysis assumed a strong conservation ethic, the total U.S. consumption would rise to only 92 quads of energy. Thus, renewables could provide our nation with nearly 20% of its energy.

While some of the conclusions in these analyses vary, a major common inference is that: the contribution from renewable energy technologies will grow significantly in the near future, both in relative and absolute terms. Not as readily apparent, however, is that most of the growth may occur in the emerging technologies. While hydroelectric power and the burning of wood and wastes may increase their contribution by as much as three more quads by 2010, the increase in energy from the emerging technologies should more than match this.

By the turn of the century, for example, photovoltaics should be adding more than 1 billion watts of capacity per year to the nation's power grid, and maybe as much to remote applications. By that time the cost of PV electricity will have dropped below 6 cents per kilowatt-hour, making it competitive with the most economic of current generating alternatives.

With well-managed "farms" and efficient use of MSW and agricultural waste, the United States could produce between 130 and 260 billion gallons of ethanol per year.

There is also an enormous potential for gasoline additives and ethanol from wood, and for ethanol from other biomass. With further research and development, prices of ethanol from wood, for example, could decline to 60 cents a gallon within a decade. With these prices, and with well-managed "farms," and efficient use of MSW and agricultural wastes, some SERI scientists believe that the United States could produce between 130 billion and 260 billion gallons of ethanol per year. This is more than enough ethanol to run our entire transportation fleet. Of course, no one expects ethanol to penetrate the market soon on a scale that even approaches this magnitude.

These are just two examples of where growth will occur. We will also witness increasing contributions from geothermal, wind, solar thermal, ocean thermal, and other renewable energy technologies.

The Potential of Renewable Energy Is Enormous

Our present technologies could economically provide 20% to 25% of America's energy needs.

It is undeniable that America's renewable resource is vast; so large, in fact, that it is difficult to comprehend. Even the theoretical potential of how much of this resource we can economically tap is hard to quantify because it depends largely on our technologies and how they progress. But we can say that our present technologies could economically provide up to 20% to 25% of America's energy needs. And we can say that, with continued research and development, that percentage will only get larger and larger. That is, as our technologies become more innovative, efficient, and cost effective, we will be able to recover progressively more of this vast solar resource. And the United States will become increasingly more energy independent.

Renewable Energy Technologies are Making Rapid Progress

In the past decade renewable energy systems have become increasingly reliable, more efficient, and longer lived.

We have made great strides. Renewable energy systems have become increasingly reliable, more efficient, and longer lived. The cost of energy derived from most of these technologies has decreased by an order of magnitude and more. These advances have resulted in emerging markets for most of the technologies. Where more than a decade ago there were virtually no markets in the renewable energy technologies, today the markets are significant and their potential is substantial, especially for distributive uses and stand-alone applications. The international market alone, where distributive systems are finding their first and widest application, are already worth hundreds of millions of dollars per year and growing.

The markets have grown primarily because of the scientific and technological advances we have made. Compared with where we were ten years ago, our theoretical understanding of the basic conversion phenomena, the solar resource, and the pertinent materials sciences is much advanced. Our scientific and technical data base is more extensive, and we have a better comprehension of the factors limiting the technologies.

Scientific and technical progress is replete throughout the renewable energy technologies: photovoltaics, wind energy, buildings research, biofuels, solar thermal, and the rest.

Photovoltaics. When the DOE started the National Photovoltaics Program a dozen years ago, photovoltaic systems were used almost exclusively to power satellites. Now, the United States has installed tens of thousands of photovoltaic systems around the world. They include large systems, like a 6.5 megawatt installation in California; small systems that pump water in Nigeria or light a cabin in the Montana mountains; and intermediate-sized systems, like Alabama Power's 100 kilowatt amorphous silicon installation. What the Coast

Guard is doing serves as a paradigm example of the increasing utility of photovoltaics. It currently has more than 10,000 photovoltaic systems to run its buoys and remote communications, saving the Coast Guard millions of dollars. Moreover, the Coast Guard plans to install 6000 more systems because no other alternative is as inexpensive and dependable in remote applications.

Since the time when photovoltaics were exclusively used in space, the cost of photovoltaic electricity has plummeted by more than 100 fold.

Since the time when photovoltaics were exclusively used in space, the cost of photovoltaic electricity has plummeted by more than 100 fold. In fact, in the last twelve years, the cost has dropped from more than $7 per kilowatt-hour to approximately 25 cents per kilowatt-hour. In the same span, the lifetime of photovoltaic modules has gone from less than five years to more than twenty years for the new generation of crystalline silicon modules.

Researchers have discovered many new semiconductor materials. Two of these new materials, amorphous silicon and copper indium diselenide, now appear to be the front runners for the large and looming thin-film photovoltaic markets.

In the last year alone, program related research set almost two dozen new efficiency records.

Perhaps the most visible indicator of progress is the continued increase in efficiencies of the various photovoltaic materials and devices. Efficiency is important because the more efficient a device, the more sunlight is turned into useable electricity, and the cheaper that electricity becomes. Virtually every material has seen dramatic increases in efficiency in the last dozen years. Devices made of thin-film materials, for example, have gone from less than 1% efficient to greater than 14% efficient. Even in the relatively mature technology of crystalline silicon, efficiency records have nearly doubled, with some devices reaching past 29%. What's more, the progress in photovoltaics has been consistent. In the last year alone, for example, program-related research set almost two dozen new efficiency records.

But researchers are not resting on their laurels. They are designing multijunction cells that could eventually enable photovoltaic devices to reach conversion efficiencies as high as 35% to 40%. Add to this the steady improvements occurring in cost, reliability, and fabrication techniques and photovoltaic energy systems appear to be headed for a bright future.

Since the mid-1970s, the cost of wind-generated electricity has dropped from more than $150 per kilowatt-hour to between 8 and 12 cents per kilowatt-hour.

Wind Energy. Since the mid-1970s wind energy technology has progressed rapidly. Improvements in the cost, performance, and lifetime of wind machines have reduced the cost of wind-generated electricity from more than $150 per kilowatt-hour to between 8 and 12 cents per kilowatt-hour. The reduction in cost and the improved reliability are big reasons for the dramatic rise in wind-generated electricity in the United States. Although wind energy conversion systems are quite useful for dispersed applications, the U.S. employs them mostly in wind farms, where they supply supplemental power for utilities. California is the pioneer in this field, with about 2 billion watts of installed capacity.

The DOE research program has enabled advances in other areas of wind technology also. We have, for example, improved our understanding of wind shear — the variation in wind speed with height above ground. And we understand better the vibrational characteristics of wind turbines and the loads induced by gravity, centrifugal forces, and average wind conditions. We have also improved components and subsystems such as (1) advanced teetered motors, which reduce the loads induced by wind sheer; (2) more flexible towers and drive trains, which weigh and cost less; (3) improved gearboxes; and (4) improved fabrication techniques for steel, wood, and fiberglass blades.

Researchers have also developed a new family of airfoils that satisfy the unique requirements of fixed-pitch, horizontal-axis wind turbines. These designs avoid the undesirable performance characteristics of aircraft airfoils used in early wind turbines. And, in resource assessment we are beginning to understand the micro-environment — the effects that natural and man-made objects have on local wind patterns.

Researchers have also investigated the environmental effects of wind turbine operation, particularly noise and radio or television interference. This research has provided the basis for the industry-wide consensus on noise measurement techniques currently being developed by the American Wind Energy Association.

Buildings Research. In this technology, we help natural processes through materials research, lighting research, and innovative designs that more efficiently heat or cool our buildings. Perhaps the best way to understand the progress of the last twelve years is to review a few examples.

Innovative phase-change materials change their state as they absorb heat during the day, and then by reversing phase change, release their stored heat at night when it is cooler.

One innovative concept is *phase-change materials*. These materials change their state as they absorb heat during the day, and then by reversing phase change, release their stored heat at night when it is cooler. This has an obvious function for space heating. Researchers improved this phase-change idea by making materials that change from one solid state to another at room temperature (solid-to-solid), absorbing and releasing thermal energy as they do so. With more development these materials could be incorporated into common building materials, such as particle board and gypsum wallboard, to produce lightweight building components with high thermal storage capacities.

Two new concepts devised for space heating and cooling are the electrochromic window and the vacuum window. *Electrochromic windows* have a thin coating whose optical transmission can be changed electrically, thus controlling the amount of solar energy passing through the window. *Vacuum windows* use a high-vacuum space between two glazings with low-emittance coatings to achieve an insulating value nearly equivalent to that of a solid wall.

Vacuum insulation could displace large amounts of chlorofluorocarbons currently used in refrigerators and

Vacuum insulation uses a high-vacuum between sheets of metal. This innovation has a very high insulation value. It is lightweight and compact and could be used to replace the bulkier, heavier chlorofluorocarbons currently used in refrigerators and freezers. It could also be used in refrigerated transports, thus helping the trucking industry to save on transportation energy.

Researchers have improved on ways to cool and heat houses using solar energy. One concept is the use of *desiccant materials*, such as lithium chloride and silica gel, to absorb water out of the air and exhaust the water outside the building. This is especially useful for space cooling in humid climates. But the use of known materials is just one of the possibilities. Researchers have also discovered several new organic materials with high moisture absorptivity that look as promising as desiccant materials for solar cooling.

Researchers have also created techniques that allow architects to design buildings so that they may make better use of natural daylight, conveying it into the interior of buildings. These efforts in lighting research can save enormous amounts of energy that would otherwise be used for lighting and cooling office buildings.

Biofuels. This is a vast area of research where we are finding ways to derive energy from wood, herbaceous crops, or agricultural and municipal wastes. Although the energy from biomass can be produced in all forms, our research has concentrated on liquid and gaseous fuels. *Liquid fuels* include ethanol, methanol, diesel, and gasoline derived from wood and waste, and diesel and gasoline obtained from microalgae and plant oils. *Gaseous fuels* include biogas, synthetic gas (syngas), and hydrogen.

We have made substantial progress in all these areas of biofuels research. Perhaps the best way to explain the type of advancement being made is to recount the progress in just one area: the development of ethanol from wood.

> Ethanol, which can be made from trees, grasses, and common agricultural crops such as corn and other grains, could be the automobile fuel of the future. It can be blended with gasoline in non-modified engines (today, many cars use a blend that is 9 parts gasoline and 1 part ethanol), or it can be used by itself in modified engines. Brazil, for example, already fuels half of its cars on ethanol derived from sugar cane.
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> Most commercial ethanol from fuel is obtained by fermenting grain. There are two basic problems, however, with ethanol moving into large-scale production from crops. First, ethanol from crops cost too much. Second, crops for fuel could compete with crops for food. SERI research may have the solution to both of these problems — ethanol from wood.
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> Ethanol from wood would not compete with the world's crop lands because to grow wood you use land that is marginal or unfit for food crops. Nor would it have to endanger forest ecosystems. For one thing, you could use proper forestry practices where trees would be treated as a rotation crop for fuel. In this vein, researchers from SERI, Oak Ridge National Labs, and others are genetically selecting short-rotation woody crops for fast growth, harvesting, and replanting. Also, wastes from the timber industry, such as sawdust and bark, may be used for ethanol production.

SERI researchers have cut the cost of wood-derived ethanol from $4.00 per gallon to $1.35 per gallon. Further research should soon drop the cost to about 60 cents a gallon.

> SERI researchers have been making advances that will eventually make ethanol from wood cost-competitive with gasoline. Just in the last decade SERI researchers have cut the cost of wood-derived ethanol from $4.00 a gallon to $1.35 a gallon. They have done this by converting progressively more of the wood into ethanol. When they first started they could only convert about 30% of the wood into ethanol. Their latest process promises to transform more than 70% into ethanol.
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> Through our research, we will eventually be able to utilize almost 100% of the wood and thus drop the cost of ethanol from wood to about 60 cents per gallon.

Solar Thermal. A solar thermal system converts sunlight to useful energy forms by concentrating the sun's radiation to produce high temperatures. The system then converts this energy into process heat, electricity, or products such as chemicals. A little more than a decade ago, this field was untouched. Since then the technology has progressed rapidly.

Since the DOE program began, we have improved solar thermal systems on all fronts, developing better concentrators with higher ratios of concentration, longer-lasting and cheaper reflective materials, and a variety of receiver and reactor systems. For example, SERI researchers developed low-cost, highly reflective, lightweight stretched-membrane heliostats that can be used in either parabolic dish collectors or in central-receiver systems.

Because they are modular, solar thermal systems can generate electricity economically at power levels that range from tens of kilowatts up to hundreds of megawatts. Modularity offers the additional advantages of short construction times and incremental investments.

These advantages are part of the reason that Luz International, Ltd. installed 195 megawatts of solar thermal generating capacity in Southern California. The Luz plant, which is privately financed, will grow to 575 megawatts in the next few years. Luz claims that the electricity they generate will cost about 8 cents per kilowatt-hour.

Solar thermal systems can be used for destroying toxic wastes, providing process heat, generating electricity, producing chemicals, and processing space-age metals and ceramics.

Besides process heat and electrical generation, solar thermal systems can be used for many other applications. Because of the high concentrations they achieve and the unique characteristics of the solar flux, solar thermal systems can be used for destroying toxic wastes, making chemicals, liquefying coal, and processing space-age metals and ceramics.

These more sophisticated applications, however, require higher concentration ratios and more advanced receiver, reactor, and conversion technologies. Researchers are working on these concepts and just over the past couple years have developed two unique concentrator systems. One system achieves concentration ratios up to 65,000 suns while the other reaches past 50,000 suns. These achievements extend well beyond previous plateaus and bode well for the future of solar thermal systems.

Through the science of photoconversion we have begun to understand the basic processes fundamental to all life — how the photon energy in light interacts with green plants to produce life, food, and energy.

Other Technologies. This is just a brief review of the things accomplished in the renewable energy technologies since the beginning of the DOE programs. There are many other technologies to consider. In *ocean thermal energy conversion*, for example, researchers designed a system that will not only produce electricity from the temperature gradients of the ocean but that will supply fresh water for drinking and for aquaculture. Through ongoing research in *resource assessment*, we understand the solar resource much better, have substantially increased our resource data base, have designed sophisticated resource models, and have developed instrumentation for accurately recording and analyzing the solar resource. And in *photoconversion* we have begun to understand the basic processes fundamental to all life — how the photon energy in light interacts with green plants to produce life, food, and energy. It is through such research as photoconversion that we will be able to analyze the process of photosynthesis in plants and learn how to capture the energy of the sun to produce an abundance of fuel, chemicals, and food. From light will come life.

Renewable Energy Technologies Help Our Nation's Energy Security

Renewable energy technologies can help our energy security. First, because the resource is vast: every state has ample and indigenous renewable energy resources that cannot be interrupted and that can help our nation become less vulnerable to disruptions of energy supplies. And second, because research and development has given us a wide and growing set of renewable energy technologies, we can tap numerous renewable energy sources to provide every form of energy.

But today we sit at a vital juncture of our energy future. Research has paved the way for the development of many promising technologies and is pointing toward the creation of others. Like any gathering bank of knowledge, solar energy research is preparing to accelerate into a profusion of applications. For the time being we have a relatively stable and calm energy picture in this world. There seems to be ample supplies of oil. We currently have a "gas bubble." And coal supplies are abundant. We can use this lull to rationally prepare our renewable energy technologies for the energy and environmental needs that are beginning to loom on the horizon. As long as we don't starve our R&D programs and drain the strength of carefully nurtured inertia, we will be able to build the renewable energy technologies so that they will provide a substantial and growing portion across the entire spectrum of our energy requirements.

Renewable energy technologies can help us light, heat, and cool our buildings.

Renewable energy technologies can help us *heat light and cool our buildings*. This is the largest energy consumption sector of our energy economy — 27 quads of energy in 1987. The renewable energy technologies can help through solar building materials, which efficiently capture and store the energy of the sun; building design for efficient and pleasant use of the sun and shielding from weather; lighting technologies and techniques, where new technologies save substantial amounts of electrical energy, and where proper design and orientation of building, windows, louvers, and skylights will help light entire buildings and reduce cooling loads; and solar electric technologies, which can provide supplemental electricity for a building or can meet its total electrical requirements.

Some believe that, by using the renewable and conservation technologies that are *available today*, the United States could save 30% of the energy it currently consumes to heat, light, and cool its buildings. And with the technologies coming down the pike, we could do even more.

Renewable energy technologies can supply us with transporation fuels: ethanol, methanol, crude oil, gasoline, natural gas, hydrogen, and even "petrochemicals."

Renewable energy technologies can supply us with *transportation fuels*: ethanol, methanol, crude oil, gasoline, natural gas, hydrogen, and even "petrochemicals". For several reasons this is a very important consideration. First, our transportation system currently consumes almost 22 quads of liquid and gaseous fuels yearly (equivalent to 3 billion 784 million barrels of oil). Second, outside of petroleum (and to a much lesser degree, gas), no technology other than renewables can furnish the ample amounts of energy in the forms required by transportation. Third, our national petroleum supplies are dwindling. Fourth, supplies of petroleum and gas are finite, so displacing their use will become increasingly important as the decades progress. And fifth, the trends in our nation's consumption of petroleum are not encouraging: For the first time in nearly two decades we are importing more than 40% of our oil. In 1987, the transportation sector used 20% more oil than it did in 1974. And last month, for the first time in recent history, we imported more oil than we produced. If these trends continue, the DOE projects that we will be importing more than 3.5 billion barrels of oil by the turn of the century, which is nearly equal to the entire amount we now use to supply our transportation fleet.

Renewable energy technologies can help the United States meet its growing demand for electricity.

Renewable energy technologies can help the United States meet its *growing demand for electricity*. Some feel that the next "energy crisis" will be one involving electrical energy. The demand for electricity has been growing at 2.4% per year. If this growth rate continues, the United States will need an additional 100 billion watts of power by the turn of the century and as much as 200 billion additional watts by the year 2010. This situation is exacerbated by the fact that by 1990, 25% of our fossil fuel plants will have reached retirement age, and progressively more thereafter. A similar situation is occurring with our nuclear facilities; by the year 2020 half of them are due to be retired. Moreover, there have been very few new starts of nuclear plants in the United States, and because of regulatory and other delays new nuclear plants may take as much as 15 to 20 years from inception to on-line service. Additionally, investors have become wary of assuming the large and long-term burden that the construction of nuclear plants has come to represent.

There are a number of ways to prepare for this looming crunch in electricity generation. One way, of course, is to refurbish existing old plants and extend their operating licenses. Another equally viable way is to turn to the growing number of renewable technologies that can be reliably and inexpensively used for generating electricity: hydroelectricity, geothermal, municipal solid wastes, photovoltaics, wind energy, solar thermal, ocean thermal energy conversion, and others. In the last dozen years, cogenerators (non-utility producers) have installed 10 billion watts of generating capacity using renewable energy technologies. And the utilities have installed even more. As the emerging technologies come of age, the potential for them to add to our nation's electrical grid network can only grow.

Renewable Energy Technologies Help Our Economy

Given the proper impetus and support, the renewable energy technologies will be able to substantially help the economy of the United States. This, they can do in several ways.

Renewable energy technologies will enable us to better compete in growing international energy markets.

First, the renewable energy technologies will enable us to better *compete in growing international energy markets*. Why? Because the emerging renewable energy technologies are price competitive in most off-grid applications. Moreover, they are not only *energy* technologies, they are *high* technologies. As energy technologies, it is probable that the markets will be enormous. Energy is the life blood of all the economies of the world, and technology is the transfusion. As high technologies, they will open up new doors and spawn competition for new, large, and lucrative markets.

Already renewable energy technologies have generated sober competition amongst Japan, West Germany, the U.S., and others. In this deadly serious game, Japan and West Germany are outspending us, and have cut into our once substantial lead in the markets. In photovoltaics R&D, for example, Japan has outspent us for the last several years and has grabbed the lead in market share. If trends continue, Japan will be outspending us on R&D by a factor of more than 2 by next year. Germany is beginning to follow suit. Last year they supported photovoltaic R&D on a larger scale than the U.S., and plan to keep doing so for at least the next few years.

This trend may prove to be unhealthy for our international trade. And not just because the potential international market for the energy technologies runs into the tens of billions of dollars. The spinoff markets may be every bit as large as the energy markets. A couple of examples should suffice to indicate the possible magnitude of the spinoff markets. The biotechnology resulting from our research in the solar sciences will have ramifications in petrochemicals, plastics, pharmaceuticals, hydrogen production, food production, clothing, and more. The solid-state technology arising from research in photovoltaics will have applications in computers, optoelectronics, lasers, xerography, superconductivity, video display, etc.

Renewable energy technologies will serve our economy by improving our balance of payments.

Renewable energy technologies will also serve our economy by *improving our balance of payments*, in several ways. For one, renewable energy can displace large amounts of oil that would otherwise have to be imported. As we have pointed out above, ethanol production currently displaces more than 800 million gallons a year. That helps us save about $300 million at the present cost of imported oil. As R&D continues to lower the cost of liquid fuels from renewables, the amount we save will escalate quickly.

Second, we can use renewable energy technologies to displace electrical energy that we might otherwise have to import from Canada. The NERC estimates that by 1995, if trends for electrical demand and capacity being built continue, the United States will import more than 120 billion kilowatt-hours from Canada. At five cents a kilowatt-hour, that would translate into $6 billion a year.

Third, rather than import energy technology, we can export it.

Renewable energy technologies will aid our economy because they produce jobs.

Finally, the renewable energy technologies will aid our economy because *they will produce jobs*; eventually, tens of thousands of jobs. What's more, they will produce them in every state of the Union. That's because every state has ample renewable resources: plants, water, wastes, sunshine, etc. So renewable systems can be built in any state.

Renewable Energy Technologies Help Protect Our Environment, and Provide a Needed Tool to Help Us Mitigate Global Warming

The European Community recently completed an extensive analysis of energy technologies and concluded that the renewable energy technologies are the most environmentally benign. To many in the scientific community, this is a well-known fact. Most renewable energy systems, for example, do not lend to acid rain because they emit neither sulfer dioxide nor nitrous oxides.

This is not to say that the renewable energy technologies are environmentally pure. When you dam a river for a hydroelectric plant, you do alter the local ecology. And when making photovoltaic modules, you may use substances that could be dangerous or toxic. But once you install a photovoltaic system (or wind system, etc.), it produces no fumes, no noxious substances, and no by-products at all — just electricity.

Solar research is resulting in processes that use light and chemistry to destroy toxic wastes and purify polluted water supplies.

The environmental advantages of renewable energy technologies do not stop there. Some renewable technologies could also hold the key to getting rid of unwanted and harmful substances produced by modern industrial societies. Solar research is resulting in processes that use light and chemistry to destroy toxic wastes and purify polluted water supplies. In the presence of catalysts, light breaks apart the bonds that hold atoms together in wastes or other chemicals. Whether it be large amounts of concentrated industrial wastes or dilute concentrations of toxic chemicals in a city's water supply, the end result of this treatment is carbon dioxide, water, and perhaps some minerals.

Compact vacuum insulation, a technology resulting from solar energy R&D, could replace insulating foams made from chlorofluorocarbons.

Another technology resulting from solar energy R&D, compact vacuum insulation, could replace insulating foams made from chlorofluorocarbons (CFCs). CFCs are widely regarded as the chemical culprits responsible for the depletion of the Earth's ozone layer. And they are one of the major gases lending to global warming. It is especially in mitigating global warming that renewable energy technologies are essential.

The way to stem global warming and thus temper the accelerating ramifications that follow, is by decreasing the amount of greenhouse gases we pour into the atmosphere. Two of the most important of these are the CFCs and carbon dioxide, since CFCs will be responsibile for about 20% of the warming and excessive carbon dioxide for about half of it. The world is starting to work toward the elminination of CFCs. And as we explained, the renewable technologies can play a major role in replacing the CFCs.

Renewable energy technologies, along with conservation technologies, offer mankind the best alternative to carbonaceous fuels and an eventual way out of the global warming conundrum.

Carbon dioxide, however, is a more intransigent problem, because most of the excessive carbon dioxide released into the atmosphere by man comes from burning carbonaceous fuels such as coal, oil, and gas. The attempt must be to gradually wean societies away from dependence upon carbonaceous fuels.

We are suggesting that the renewable technologies, along with conservation technologies, offer mankind the best alternative to carbonaceous fuels and an eventual way out of the global warming conundrum. Photovoltaics, solar thermal, wind energy, hydroelectric power, and other renewable energy technologies do not produce greenhouse gases. Even biomass energy technology (energy from wood, grasses, etc), which depends upon carbonaceous fuels, does not promote global warming. This is because proper utilization of biomass energy would be in harmony with the natural carbon cycle. To produce biomass for energy you plant, grow, and harvest trees, grasses, or other plants. This results in the absorption of as much carbon dioxide out of the atmosphere as would be put back in upon the combustion of biomass energy products. That is, you establish an equilibrium.

These technologies are available to us today and can make significant impacts, now, on the environmental strains we are putting on the world. But future renewable energy technologies hold even greater promise for our nation and the world. One example would be hydrogen produced from solar energy. To get the hydrogen, your resource could be water. To produce hydrogen, you may only have to rely on sunlight. And when you burn hydrogen, you would produce only energy and water vapor, which replenishes your resource.

Continued Progress Requires Consistent Support

Progress made to date is a function of Congressional support, sound management, and solid scientific research.

The progress that has been made to date is the function of three essential ingredients: Congressional support, sound management by the U.S. Department of Energy, and solid research by scientists at the Solar Energy Research Institute and around the country. Continued progress will depend upon the same three things.

To date, Congress has invested approximately $2 billion dollars in renewable energy R&D. Substantial returns on that investment are beginning to roll in. Research in geothermal, wind, and biofuels is resulting in billions of kilowatt-hours of energy annually. And we are enjoying millions of kilowatt-hours of energy yearly from the research done in solar thermal and photovoltaics. Renewable energy technologies are providing America with growing and secure supplies of domestically developed and controlled energy; energy that displaces the need to import even more foreign oil; energy that provides America with an export market and helps it with its balance of payments; and energy that makes America more technologically competitive in the world and that produces jobs for Americans.

When deliberating budget allocations for energy R&D, one should consider the potential of the technologies. The renewable energy technologies have enormous potential. This is substantiated by the returns thus far, and the future promises much more:

- SERI research has reduced the cost of wood-derived ethanol from $4.00 a gallon to just under $1.35 in just ten years. With continued support we can get than to less than $0.60 per gallon.

- Continued work on the vacuum insulation technology being explored by SERI scientists offers the best way for America to be able to eliminate CFCs and still offer improvements in appliance efficiencies.
- Improved photovoltaic materials will further reduce the cost of PV-produced electricity. We must remember that many of the materials being touted as likely "winners" in today's growing PV market did not even exist ten years ago. They were all developed under the DOE's research program, most of them in close cooperation with American industry. It is most likely than in another ten years " the winners" will be materials that have not yet been developed.
- We will continue to develop technologies whose use produces neither toxic fumes nor toxic wastes.
- We are developing solar technologies that will allow us to destroy toxic wastes and to purify polluted water sources.
- Emerging renewable energy technologies will offer one of the major strategies that will be needed to help the international community address the global warming issue — new energy supplies than can provide heat, fuel and electricity without adding to the growing concerns about carbon dioxide.
- "Smart windows" and other lighting and buildings technologies will save America many quads of energy.

After a scientific "breakthrough," there remain decades of hard, disciplined work before the benefits of the breakthrough can be realized.

However great the potential of renewable energy technologies is, it will only be realized with many more years of hard work. Let me address a pet peeve of mine. As a scientist, I get tired of being asked "When are you going to make a breakthrough?" As a man who has done some years of laboratory research, and managed research for more years than I might care to disclose, I know personally that solid scientific progress and technological innovations are built more on perspiration than inspiration. The popular press likes to talk about "breakthroughs," but the reality is that after the breakthrough there remain decades of hard, disciplined work before the benefits of the breakthrough can be realized. I am sure that high-temperature superconductivity will prove to be an example.

If Congressional support abates, the progress in solar energy R&D will abate with it.

I don't discount the importance of original thinking to science and technological development. But I must point out the importance of sustained effort. This Committee, and the Congress have provided the needed support for the research and development of renewable energy technologies for twelve years now. This support must continue. If it abates, the progress will abate with it. The opportunity exists to support the growing return that we will see on the investment in renewables. The access to the resource is only limited by technology. The progress that we have made in just over a decade is surely a precursor of the progress to come.

The renewable energy program has demonstrated both progress and promise sufficient to deserve stable, long-term commitment and a centerpiece laboratory housed in adequate permanent facilities.

The continuing decrease in the budget for R&D on renewable energy is a real matter for concern. It deserves serious re-examination in light of a new administration and shifting priorities. The renewable program has demonstrated both progress and promise sufficient to deserve stable, long-term commitment and a centerpiece laboratory housed in adequate permanent facilities.

This Committee and the Congress have the opportunity at this time to continue America's sound investment in renewable energy. Such an investment will help secure America's energy future, improve our technological competitiveness, help with our balance of payments, and assure the continued development of one of the major strategic responses to concerns about global warming. I thank you for inviting me to testify.

PANEL 2 DISCUSSION

Mrs. LLOYD. Thank you very much, Dr. Hubbard.

As you expressed your concern in listening to Dr. Darman and reviewing the hearings on Admiral Watkins, and there is a concern for environmental reasons, do you feel that the directives for the reduction in the solar budget strictly came from OMB or is it any indication of the philosophy of this Administration?

Dr. HUBBARD. My impression is that the budget that was put in front of you stems primarily from OMB's attitude in the last Administration.

Mrs. LLOYD. Well, as you know, this Committee has always been a friend to the solar program.

Dr. HUBBARD. Sure.

Mrs. LLOYD. But we would appreciate a little bit of help along the way.

Dr. HUBBARD. I can understand that, and hopefully you will get a little bit more in the future than you have in the past.

Mrs. LLOYD. We'll do the best we can.

How important do you think the hydrogen program is to our energy research, and what kind of role should we take in this? The time has come that we can't just say yes, we are for these programs and continue to down the funding. It seems to me we are at the level that this is the year that we have to establish some priorities. Even though some programs are good programs and the program has merit, we do see a decreased level of funding. We don't have enough to go around to make any meaningful dent in research or development of a technology, and we have to either go with a program or not go with it. We can't continue just to put a little, bitty, piddling sum into these programs.

Dr. HUBBARD. The hydrogen program has been something of an orphan child. In fact, within DOE or at least within Conservation and Renewable there has not been a hydrogen program as such, and a hydrogen program probably should be conceptualized and defined. I think that's more important now as the concern about carbon dioxide increases than it was before.

I was interested in what Dr. Walker had to say. He said was he correct in assuming that hydrogen is an energy source, or I believe that is a paraphrase of what he said. That really isn't correct. Hydrogen is not an energy source. It is an energy storage energy vector. It is an excellent fuel, but by any means I know in which one can produce energy and produce hydrogen, you put more energy into it than you get out of it. Now that's not to say that there isn't merit in hydrogen. It has peculiar characteristics that makes it particularly effective for space travel or for the aircraft we're talking about.

It is a clean-burning fuel above all. It's the cleanest burning fuel that we have, and it does not produce CO_2 when it burns, and it does not normally produce nitrogen oxide.

So it is an energy vector and it is a potentially non-carbonacious transportation fuel, it is a chemical reagent that can extend and make more effective and more efficient the utilization of both coal and biofuels. So it has a potentially important role to play.

If you ask the Department, and I think you did ask Donna Fitzpatrick this question last year, she won't say, and it's accurate that approximately $35 million is spent on hydrogen. That's true, but most of it is spent in the context of the space program or military and space exploration or the fusion program. Not very much of it, only about $4 million of it is spent in the context of how hydrogen relates to conservation and renewable or how hydrogen relates to a general transportation fuel.

I attended the hydrogen project review in Miami, the same one Dr. Block referred to, last week. The general quality of the work frankly was higher than I expected that it might be. As Dave said, there is coordination within that program. I don't believe, and we reached this conclusion down there, that it's not really adequately focused or really thought through in terms of how it relates to the rest of the program. I think that should be done and I think it could be done and would suggest to the Committee you might request that the Department provide you with something like that.

Mrs. LLOYD. Thank you very much.

Mr. Hutchison, would you supply for the record some more information on solar chemistry for cleanup of groundwater.

Mr. HUTCHISON. Well, it shouldn't be too hard to imagine if you think about photosynthesis where sunlight converts CO_2 and water to glucose and cellulose and things grow before our very eyes almost like magic, it shouldn't be too hard to imagine that we could reverse the process in a way.

We call the process photolytic. It has a photo effect, and quite often we will drive this chemical reaction with a catalyst. It may be a thermolytic, a thermal process enhanced by the photon effect, if you will.

There are two basic approaches now. One is a thermal, a pyrolytic and photolytic process together and you need very high concentrations and very high temperatures. So we are using the dish concentrator. We have a quartz jar, if you will, and inside that quartz jar is a foam ceramic, very simple, onto which we have plated rhodium, a metal, and we pass a gas over that rhodium plated foam when it's in concentrated sunlight and these organic solvents are reduced or destroyed or brought to very simple chemicals like table salt and water.

Now we have another approach, the low concentration approach, and that's aimed primarily at cleaning up contaminated water where you would have things like chlorinated hydrocarbons like vapor degreasing solvents or paint solvents in the range of say two to five hundred parts per million. This stuff is really hard to get out of the water through standards means, and there are some areas where we have so much contamination in the water that it's not even usable for agriculture.

Well, we can put a field of heliostats, these large flat mirrors and drill a well, bring the water up and pump it over a big aluminum plate, let's say the size of that mural, and we could have 30 heliostats say 30 feet in diameter in the back. We could pump this water over this aluminum plate at hundreds of gallons per minute mixed with the titanium dioxide powder and the sunlight will destroy these acetone, keytones, chlorinated and fluorinated hydrocarbons and simply reduce them to benign materials. It does it at a low cost because it's a very simple system. All you have is a mirror and a big aluminum plate and pumps and holding tanks.

That water could then be used for irrigation or maybe this concept might even be part of the sewage treatment program where you have really difficult to deal with chemicals in small quantities.

Also, there is another side effect, and that is we all know that ultraviolet light destroys bacteria and organisms. So you get that side benefit. You would actually disinfect the water.

So there are two basic approaches, low concentration, low temperature and low concentration of flux, and then high, hot approaches, high temperature and high concentration.

Mrs. LLOYD. Thank you very much.

I think that all of you have probably seen the article in this morning's Washington Post about the Luz solar plant signifying the major breakthrough in alleviating utility concerns about the use of solar energy. To me this seemed like it might be a mixed blessing since it is this far along, that there may not be any more R&D dollars. Do you all want to comment on that?

Mr. SKLAR. Yes, I think I ought to. It took many years to get the technology out the pipeline and to get it into the marketplace, and this was technology that we worked in the 1970's through this program, and then it took us years to build consumer confidence and investor confidence to use it on the scale today, and it's a major breakthrough obviously, as the article says.

We have better technology in place, in the pipeline, that needs to get out, and I guess my testimony to you was that if you stagnate into what you see out there from the 1970's when our technology is very much like computers are today with a new model and a new breakthrough every few months, those new technologies that will make this obsolete are not going to come from here. It will be coming from abroad.

What was interesting is in the early 80's when we as an industry came up and didn't have 200 megawatts worth of power up on line, everybody said no way, it's not going to happen, it's a pipe dream and you can't get it out the door. Well, we did. It's an example. It's a positive demonstration of just sticking with it for a while.

I guess our message is if you stick with this for a while in a very small program, and we're not talking, you know, $300 million-plus like the nuclear program. This is a $15 million or $20 million a year program. You will see breakthroughs that will dazzle you.

Mrs. LLOYD. I noted that the State of California has tax laws that are beneficial to developers and marketers to develop alternative sources of energy. Do any other States have similar laws?

Mr. SKLAR. Sure they do, and there are 37 States that have different kinds of incentives, both for consumer and commercial application, and even many utilities are starting to develop incentives to stop their peak power demands at noontime for cooling. So the States see this, and again technology development in this country has to be a partnership with the research laboratories like SERI, the industry like Gus and the State governments and Federal Government being the facilitators and catalysts to get it out the door, and California is a perfect example in that they are willing to commit with the Federal Government and the industry and the research community.

Mrs. **Lloyd**. Well, very good. Thank you for your testimony and your good answers.

Mr. Morrison.

Mr. **Morrison**. Mr. Sklar, the Japanese, well the competitors all around the world, but particularly the Japanese and West Germans are placing their research emphasis in solar energy. Where are they making that investment to perhaps lead them to the greatest success?

Mr. **Sklar**. Well, what they have done, and again taking Japan for an example, we are not different than any other high-technology industry they have been looking at. They have worked with a smaller group of players, let's say, than the U.S. photovoltaic industry. Their PV industry is smaller than ours, and they have really developed a fairly long-term set of commitments to that industry lasting 5 to 10 years, and what's nice about it, have kept it.

What they have done has been looking into it in three ways. One is using their research program on amorphous silicon development, and albeit it's true that it has mostly been to the consumer market it has been relating to. They are starting to make inroads in the remote power market. Remember, 65 percent of this technology is exported from this country that we manufacture in the world markets.

So their tact is tied aid where they use their Third World development program and they give them money and they use that to build sales for their industry. The European community is doing the same thing. This year, 1989, they are giving $30 million dollars to Saharan African countries, and that is to buy photovoltaic water pumps, and it's tied to European photovoltaic manufacturers, smaller than ours, a smaller group of companies. That $30 million over three years will take the European manufacturing capacity beyond the United States even though it's a small part of it because they develop a market.

So they have an R&D program that they are increasing. In Germany now it's $60 million-plus. So that's almost twice our R&D effort. Tie it to a market development program in the Third World, and you're going to see a very dynamic industry. So they are looking at both a short-term market sector and then long-term high technology, and it's a nice mix and it works.

Mr. **Morrison**. Their persistence, as you've used several times, looks like it's paying for them.

You mentioned the international program and gave it some credit. Can you give me specifics on what that has done on expanding opportunities?

Mr. **Sklar**. Yes. I can give you four, and I'm sorry I didn't bring one of my most stellar examples. I normally, as Nancy knows, bring tons of materials here. But one thing that U.S.A.I.D. just produced as a cost share with the Department of Energy under this program is a booklet on renewable energy applications, and what it is is a series of pictures and graphs that show the uses of photovoltaics, solar, thermal, wind, biomass and micro hydropower as absolutely cost competitive against diesel.

As I testified last week in front of the House Appropriations Foreign Operations Subcommittee, most of our development in the Third World goes to promote diesel generation, and these poor

Third World countries are having to import diesel fuel aside from the Japanese making 87 percent of the world's diesel engines. That's just not a very sound policy either for Third World debt or our own renewable energy industry.

So to have the U.S.A.I.D. publish with the Administrator's signature and the seal of the U.S.A.I.D. on a book that shows these are the five or six technologies and these are the 10 or 12 niche markets and look at these graphs and they are in beautiful color, we are able to bring it to the U.S.A.I.D. Mission Directors in countries and customers and say, look, the U.S. Government is telling you that when you have a medical refrigerator or water pumping, that renewables can be cost effective.

We are putting on this market development conference in May as a result of sending the renewable industry into the Caribbean basin looking for real market opportunities tied to funding, the Inter-American Development Bank and World Bank, because again one of the things we found out from the Caribbean basin initiative is that U.S. business is not overwhelmed to move into places that have brownouts and blackouts six times a day, and again to foster them to import oil probably isn't a good policy.

Now it has taken us eight years to get that across to them, but the program has been useful. So those are the kinds of materials and market incentives that we have had. In fact, the program last year brought the wind industry into India. It's a good short-term market for that industry. It brought the solar thermal industry into the Cairo International Trade Fair. And because there are some great markets out there, and if you get these small companies to have a shot at meeting their customers, you're going to have sales. They're small, four stars though, a good program.

Mr. MORRISON. I appreciate that, and I guess we're looking for those. I guess the key point though is when you are promoting overseas you've got to have American companies to be able to back them up with goods to fill those orders.

Mr. SKLAR. Absolutely.

Mr. MORRISON. Mr. Hutchison, I am also fascinated by your detoxification of hazardous wastes. Do you have any idea on costs? I know this may be a relatively new technology, but, for instance, the alternatives now would be incineration and a host of other things and primarily under the Superfund just moving them around from place to place while we try to figure out what we are going to do with them.

Mr. HUTCHISON. Yes, I do. I have done a little research. I had an article, and I'm sorry I don't have it with me. I believe Vulcan Chemical Company in Kansas City produces sodium pentichlorophenol treatment for wood, wood treatment, and apparently they put the wood in a vat and continue until they get a sludge. They don't know what to do with it, and they put it in barrels and store it.

The locals found out about it and it was publicized. So Vulcan looked into an incinerator to handle this production of six barrels per month, six 55-gallon barrels per month. The cost of the incinerator was $4.5 million to meet EPA standards.

So Vulcan continues to store. As long as the barrel doesn't leave the chemical site it's considered in-process chemicals. So they continue to store and continue to store.

I have a friend who manages the largest paint company in the Southwest, and for something like 10 years they paid an average of $300 a barrel to have solvent sludge hauled off to a dump site in Arkansas. Now that dump site operator is bankrupt. It has been declared a dump site and the EPA is involved. Four thousand of the 22,000 barrels at that site are his. He paid $300 a barrel to have them hauled off, and now he is looking at a $4 million cleanup bill.

He says to me if you put a dish in my back yard so that I can destroy these solvents before they leave my plant, the elimination of the liability, the potential liability would be motivation enough.

Simpler chemicals to incinerate, chlorinated fluorinated hydrocarbons, still would require something on the order of six barrels of oil per barrel of material, and that varies greatly with what you're looking at. It is very, very expensive to incinerate, forget the capital cost. I think we are looking at a technology that will be cheaper to dispose of certain materials.

Certainly we can't make one reactor and one dish and take care of everything that comes along. But I think if we just picked on say perchloroethylene, which is a dry cleaning solvent, and when it gets dirty what do you do with it. Well, they store it. You could have a flourishing business on that one chemical I believe and very cost effectively.

We need some time. It's not something we can do overnight. We are still learning. We have only been working on this for a year.

In last year's testimony you will recall I mentioned it just briefly. I had just heard about it. We have only got one year's experience.

Mr. **Morrison**. Well, I hope your progress in future years can match what has happened in this last year.

Dr. Hubbard, just to you, one of our star witnesses, we are really struggling on this Subcommittee to try to make a measurement of what America really needs, and I think transportable liquid fuels certainly fit in that category.

I'm fascinated by your potential from wood and other renewable sources. Does that 60 cents a gallon include the raw material as well as the cost of processing? I mean are we working now on getting closer to say a hundred percent of efficiency on conversion?

Dr. **Hubbard**. Well, appreciably closer. As you probably know, lignocellulose is a complex material and really has three components in it, and the xylose component and the lignin have been the two things that have been hard to deal with. So through a combination of genetically engineered fermentation microbes, fermentation yeasts, we are now a lot closer to being able to use that a hundred percent.

The 60 cents is not a very firm number. We think we can get to that and the people in the laboratory say so. I'm not yet saying that I can guarantee that. The $1.35, that's pretty realistic and that we would stand behind.

I think one of the things we can do is move beyond the issue of wood per se into the processing of herbaceous plants, energy row crops is what that would amount to based on variations of sorghum or variations of grasses, and if we can do that, then we may be able to move even beyond the 60 cents, but that's no small job. That's a decade to a 15-year job I would suspect.

Mr. **Morrison**. So some of these very rapid growing crops which pull a lot of carbon out of the air could potentially be converted into fuels and we're really addressing several problems at once.

Dr. **Hubbard**. Yes, that's a real possibility, but not yet doable.

Mr. **Morrison**. Crab grass into gasoline. [Laughter.]

You've got a real winner. That's a twofer if there ever was one.

Dr. **Hubbard**. In one of our brochures I think we've got a sign that says "put a tree in your tank." Well, we can take that a little bit further now. [Laughter.]

Mr. **Morrison**. Thank you.

Mrs. **Lloyd**. It's always delightful to hear from you gentlemen. Thank you very much.

Our next witness is Dr. Paul Tarman who is Vice President of the Institute of Gas Technology.

Dr. Tarman, we look forward to your testimony as well. Please proceed. We have your written testimony I believe and you may proceed as you wish.

STATEMENT OF DR. PAUL TARMAN, VICE PRESIDENT, INSTITUTE OF GAS TECHNOLOGY

Dr. **Tarman**. Thank you, Madam Chairman, and good afternoon other members of the panel.

I am Paul Tarman, Vice President of Research and Development at the Institute of Gas Technology. I am here today to testify in behalf of IGT's President, Dr. Lee, who is out of the country at this time.

Today I would like to offer some recommendations regarding DOE's geopressured/geothermal research program. This program is directed at recovering energy from the vast reservoirs of geopressured brines located in the Gulf Coast area.

As you may know, the U.S. Geological Survey has estimated that the porous sandstone formations in this area contain approximately 5,700 TCF, that is trillion cubic feet of natural gas. If only 10 percent of this resource can be produced, it would add more than 30 years to our domestic supply of natural gas.

An equal amount of energy is contained in the geothermal heat of the hot brines. Therefore geopressured/geothermal energy represents a very large domestic energy resource that should be investigated and developed.

Production of this energy is accomplished by drilling into the geopressured zone and bringing to the surface a mixture of hot brine and methane. On the surface the mixture is depressurized. This causes the gas to separate from the brine yielding approximately 30 cubic feet of methane per barrel of brine. After the gas has been released and the thermal heat of the brine recovered, the brine is reinjected into a disposal well located in a nearby saline aquifer.

The objective of DOE's research program is to investigate the resource and to learn how to recover this energy in the most efficient and economical manner. The program has five technical goals. First, to confirm the existence of the resource; second, to establish its size and magnitude; third, to measure the reservoir characteristics; fourth, to develop the technology necessary to recover the energy and; last, to formulate a model capable of predicting energy recovery at other geopressured sites.

The first two goals have been achieved. The current program addresses the last three goals. DOE has assembled a broad-based research team for this purpose. The team includes Eaton Operating Company, a well digger, well drilling, the Institute of Gas Technology, the Ben Holt Company, the University of Texas at Austin, the University of Southwest Louisiana, S-Cubed Corporation, Louisiana State University, Southern University, Rice University, the Bureau of Economic Geology at the University of Texas and EG&G of Idaho.

Three wells are currently being investigated, the Gladys McCall and Hulin wells in Louisiana, and the Pleasant Bayou well in Texas.

The Gladys McCall well has produced already during the program 675 million cubic feet of natural gas and 23 million barrels of hot brine. Flow from the well is now shut down to allow wellhead pressure to rebuild. The rate at which this pressure builds up provides very valuable information for predicting the lifetime capacity of the reservoir and the flow characteristics. Core samples will be taken after pressure buildup to determine if any change has occurred in rock properties due to the previous brine and gas production.

The Hulin well is the deepest and hottest well in the program. A brine disposal well is now being drilled so that drawndown tests can be made to determine the size of the reservoir. If it is as large as expected, permanent production equipment will be installed and a multi-year test program initiated. The results from this deepest and hottest well are needed to extend the predictive range of our existing geopressured/geothermal models.

A hybrid power plant co-funded by EPRI is now being installed at the Pleasant Bayou site. This power plant will be the first to demonstrate the generation of electricity by the simultaneous utilization of both methane and the geothermal energies. A nine-month demonstration program is planned at this site after which high flow-rate tests will be conducted to determine reservoir dynamics.

To date the program has shown (a) that a huge energy resource exists both in the amount of methane and in the amount of geothermal energy, and that both can be produced at high flow rates for long periods of time without adverse environmental effects.

Although some of the program goals have been met, we have not yet completed the work necessary to model the reservoir and to maximize the energy recovery. Therefore, the Institute of Gas Technology recommends that this Committee authorize and Congress appropriate $8.4 million in 1990, fiscal '90, to continue the acquisition and analysis of both new and historic scientific data at all three geopressured sites, at Pleasant Bayou, Hulin and Gladys McCall.

Thanks for your attention and I would be most happy to answer any questions you may have.

[The prepared statement of Dr. Tarman follows:]

STATEMENT BY PAUL TARMAN
VICE PRESIDENT, INSTITUTE OF GAS TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH & DEVELOPMENT
HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
March 2, 1989

In 1987, the United States used 17.6 trillion cubic feet of natural gas. The U.S. Geological Survey has estimated that 57,000 trillion cubic feet of natural gas exist in geopressured/geothermal formations in the U.S. Gulf Coast area. Approximately 5700 trillion cubic feet of natural gas are contained in vast reservoirs of geopressured brines in porous sandstone formations. The remainder exists in impermeable shale formations, making it very difficult to produce. If even 10% of the gas present in the sandstone can be recovered, it represents an additional 30 years of domestic natural gas supply at current rates of use. In addition, an equal amount of thermal energy is estimated to be available from the hot brines.

Thus, geopressured/geothermal energy represents a large domestic energy resource that should be developed.

The U. S. DOE has a program to investigate this resource and learn how to economically produce energy from it. This program is directed by DOE's Conservation and Renewable Energy Division and managed by DOE's Idaho Operations Office. The five technical goals of DOE's Geopressured/Geothermal research program are:

- Confirm the existence of the resource
- Establish its magnitude
- Measure its characteristics
- Develop a technology to recover its energy
- Formulate a model to predict energy recovery at geopressured sites.

The program has achieved the first two goals, made progress toward the next two, and begun work on the last.

Work in the current program addresses these last three goals. A team has been assembled by the DOE to use their varied skills to help achieve these goals.

Participating organizations include: Eaton Operating Company, Institute of Gas Technology, the Ben Holt Company, University of Texas at Austin, University of Southwest Louisiana, S-Cubed, Louisiana State University, Southern University, Rice University, the Bureau of Economic Geology of the University of Texas at Austin and EG&G Idaho.

Production of geopressured/geothermal methane involves drilling a well into a productive geopressured zone and bringing to the surface a mixture of hot brine and methane. On the surface, the mixture is reduced in pressure, causing the gas to separate from the brine, yielding approximately 30 ft^3 of methane per barrel of brine. After the gas has been recovered, the brine is injected back into a disposal well located in a saline aquifer.

The current DOE program involves two wells in Louisiana, Gladys McCall and Hulin, and one in Texas, Pleasant Bayou. During the coming year, the program will address issues such as:

- maximum brine and gas production rates;
- productive lifetimes of given reservoirs;
- optimum production strategies to maximize energy recovery;
- techniques for controlling scaling and corrosion from the brines; and
- long-term capacities of disposal aquifers.

The Gladys McCall well has produced over 23 million barrels of brine and 675 million cubic feet of natural gas during the DOE test program. Flow from the well is now shut off to allow the pressure to build up after the pressure decrease from the brine and gas production. This pressure build-up will enable the reservoir engineers to learn about the reservoir's dynamic characteristics, providing information needed to predict the lifetime capacity and flow rates of the reservoir. The cores to be taken after the pressure buildup will show whether the reservoir rock has been affected by the brine and gas production.

The Hulin well, the deepest and hottest of the wells in the program, has been reworked to allow it to be produced and the brine disposal well is being drilled. The next step is to test the well with trial production and testing equipment to determine the magnitude of the reservoir. If the reservoir is as large as expected, permanent production and testing equipment will then be installed and a multiyear test program will be initiated to learn about the reservoir and its production characteristics. These results will be used to expand the models being developed to include this deepest and hottest reservoir.

A hybrid power plant cofunded by EPRI is being installed at the Pleasant Bayou well. This power plant is the first demonstration of using the combined chemical energy of the methane and the thermal energy of the brine to generate electricity. After a nine month power plant demonstration, the well will be tested at high brine flow rates to determine reservoir properties.

In summary, the program has met some of its goals but has not yet completed both the work leading to making the best use of the resource, and the modeling of the reservoir which will lead to maximizing the amount of energy that can be recovered.

The program has shown that a huge resource exists, both in the amount of methane and in the amount of energy in the brine, that it can be produced at high flow rates for long periods of time, and that this can be done without observing any adverse environmental effects.

The Institute of Gas Technology recommends that this Committee authorize and Congress appropriate $8.4 million for FY 1990 to continue the scientific data acquisition and analysis at the three geopressured/geothermal wells, Pleasant Bayou, Hulin, and Gladys McCall, including the analysis of historic data.

This concludes my testimony. I thank the Subcommittee for the opportunity to appear, and I would be happy to answer any questions you may have.

GEOPRESSURED/GEOTHERMAL METHANE

The U. S. Department of Energy has underway a project aimed at solving the technical issues associated with producing cost competitive natural gas and using the heat of the brines from the vast geopressured/geothermal resources present in the Gulf Coast area. Three wells are available to the project: Gladys McCall (LA), Pleasant Bayou (TX), and Hulin (LA).

This program requires the involvement of various organizations with expertise ranging from well operations, surface facilities and hybrid electric power plants to geology, physical chemistry, reservoir modelling, environmental studies and experimental data analysis. Participating organizations include: Eaton Operating Company, Institute of Gas Technology, the Ben Holt Company, University of Texas at Austin, University of Southwest Louisiana, S-Cubed, Louisiana State University, Southern University, Rice University, the Bureau of Economic Geology of the University of Texas at Austin and EG&G Idaho.

The project team has developed corrosion prevention treatments, specialized materials and brine handling equipment which have allowed the production of large amounts of hot brine and natural gas from the Gladys McCall and Pleasant Bayou wells. This proved the existence of these huge, previously unknown underground reservoirs. The results of this program also provide useful information for improving production of natural gas from conventional or watered-out reservoirs.

A power plant provided by EPRI which uses both the natural gas and thermal energy of the brine is being installed at Pleasant Bayou. This will be the first demonstration of electricity production using this resource. Following the power plant program, the brine will be produced at high flow rates to yield further information about the strength of the reservoir rock and the changes in the rock permeability as the reservoir pressure decreases.

The Hulin well has been refurbished and is ready for the installation of trial production and testing equipment. If the well proves capable of high flow rates, permanent production and testing equipment will be installed. The test program will expand the scientific understanding and modelling to this deepest and hottest of the three wells. It also may show the presence of free gas in addition to the gas dissolved in the brine. The presence of free gas would have a positive effect on the economics of geopressured/geothermal energy.

The final scientific testing program for the Gladys McCall well is underway to determine the effect on the reservoir of having produced over 27 million barrels of brine and 675 million cubic feet of methane during the DOE test program. The scientific understanding obtained will allow the prediction of the longevity of geopressured/geothermal reservoirs.

The scientific programs at all three wells should be continued, as valuable technical, environmental and economic information is being obtained from each well.

IGT recommends $8.4 million to continue the scientific data acquisition and analysis at the three geopressured/geothermal wells, Pleasant Bayou, Hulin and Gladys McCall, including analysis of historic data.

DISCUSSION

Mrs. **Lloyd**. Thank you very much for being with us today. This is certainly exciting technology.

It's my understanding that this Hulin well cleanup took longer than it really should have because there was hesitancy on the part of the Department to fund the program. Do you think the program is sufficiently on track now?

Dr. **Tarman**. At present, no. I think the present program funding schedule for '90 is about $2.9 million. That will not be enough monies to fund activities at all three wells. It will be enough to fund activities at the Pleasant Bayou where it will get some good information, that information being how to recover the energy, but there will be little or no activity at the Hulin well or the Gladys McCall. We will lose information on the effect of the deepest and the hottest well, and we will lose information on what happened to the reservoir after we deliver it at Gladys McCall.

Mrs. **Lloyd**. After we understand this resource, the methods for us to utilize it, is there a business in place that could then begin production?

Dr. **Tarman**. I think there are probably two businesses, the natural gas industry and the electric industry.

Right now if a gas man goes out and drills a well, when he hits brine, he plugs and abandons. He doesn't have the capability or the technology to handle this situation. So (a) we should solve this problem and provide them with the technology to take care of the brine, disposal well technologies, and once that is developed, yes, I think there would be industry available to handle it. At the present time, no. Research has to be done.

Mrs. **Lloyd**. Mr. Morrison.

Mr. **Morrison**. Are the results so far enough to stimulate any sort of industry involvement?

Dr. **Tarman**. Yes, some. EPRI has become involved. They are very interested in recovering the geothermal energy in the brine, and they are providing equipment at the Pleasant Bayou site to do the simultaneous conversion of methane and the thermal heat in the brine into electricity. Most of the equipment will be provided by EPRI plus EPRI will co-fund the operation, the above-ground operation of this equipment.

Mr. **Morrison**. How about from the gas side of the equation?

Dr. **Tarman**. From the gas side of the equation at this time, no. The gas industry has chosen to follow instead the co-production of brine and gas from watered out reservoirs, and I would venture to say that that choice is based primarily on the fact that it's a nearer-term energy resource. The production of geopressured energy is a little further out horizon.

Mr. **Morrison**. Is this resource limited to the Gulf area?

Dr. **Tarman**. Pretty much so, yes.

Mr. **Morrison**. That's the combination of geothermal and——

Dr. **Tarman**. The combination is limited.

Mr. **Morrison**. Thank you very much, Dr. Tarman.

Mrs. **Lloyd**. Dr. Tarman, I want to thank you for being here today to accommodate us. At the previous hearing we were rather crowded and cramped for time, and we appreciate you accommodating us by coming today.

Dr. **Tarman**. I appreciate your asking me.

Mrs. **Lloyd**. Thanks a lot and we certainly are interested in the good work that you're doing.

Our third and final panel today is Dr. Michael Berger, Program Director of the Energy and Technology Initiative at Los Alamos National Laboratory and Dr. Charles W. Kreitler from the University of Texas.

We welcome you gentlemen.

Dr. Berger, you may proceed.

PANEL 3

STATEMENT OF DR. MICHAEL E. BERGER, PROGRAM DIRECTOR, ENERGY AND TECHNOLOGY INITIATIVE, LOS ALAMOS NATIONAL LABORATORY

Dr. **Berger**. Thank you, Madam Chairman, and Mr. Morrison.

It's a pleasure to be here today and thank you for asking me to appear before this Subcommittee primarily to talk about two initiatives in the renewable energy program, the geothermal program in general that you just heard some about and our program at Los Alamos, hot dry rock in particular.

The second initiative is one that is sponsored by the Energy Storage Program in the Renewable Energy Office, and that is the fuel cells for transportation applications program. An interesting thing about that that I will focus on is a rather interesting partnership between Los Alamos and International Fuel Cells Corporation to develop innovative and transfer technology to industry.

Geothermal energy, as you heard, is the natural heat in the earth's crust, and there are mainly four types of geothermal energy considered in the Department of Energy's program.

The first is hydrothermal, and that is where one finds naturally hot fluids in the hot rock when you drill for it.

The second is geopressured, which you just heard about and will hear about in a moment also from my colleague.

The third is hot dry rock where it's a manmade geothermal system. We take advantage of mining heat from the hot rock in the earth.

The fourth is the magma program, which is extracting heat from magma located near volcanic sources.

The geothermal resource in this country is quite large, and DOE estimates something over a million quads. So even if we only extracted one percent of that, we're talking about a tremendous amount of energy when compared to the usage in the U.S. is something on the order of 74 quads.

I won't go into all the benefits of geothermal energy, I'm sure the words global warming and environment haven't come up today in any other speakers, but certainly geothermal energy is a renewable energy resource that has advantages in that means.

In addition, as you all know and have probably heard before, we are importing something like 40 percent of our oil in this country, and this contributes to the trade deficit, and geothermal energy technologies actually provide an opportunity for an export technology if we can improve the technology and become more competitive with the Japanese, the Italians and the people from Iceland in particular.

Geothermal energy is also a good technology from the point that it can be developed in small, affordable power plants that can be brought on line rather quickly. Most people tend to think of geothermal energy as a western resource or in the case of geopressure as a southern resource.

However, a recent study that we performed along with the Massachusetts Institute of Technology does show that for geothermal gradients located on the East Coast one can think of using geothermal energy to offset fossil fuels or things like preheating boiler fluids and in the case of our hot dry rock technology using it in a special mode that we call a huff-puff mode, using it for peaking, and it appears that geothermal is economic in this case.

About two years ago the National Research Council formed a Committee on Geothermal Energy Technologies to examine the issues of the geothermal program that DOE has. One of the things they pointed out is the fact that in 1979 the geothermal R&D budget within DOE was $158 million. In FY-1989 the geothermal technology portion of this budget is down to $15.6 million. So we are talking about a factor of 10 in 10 years roughly.

The Committee recommended funding of about $35.7 million for FY-90 and levels comparable to that in the outyears.

In my opinion, the geothermal industry in this country is at risk mainly due to low oil prices, and this was also confirmed by the NRC report. Additional R&D is needed to make the geothermal industry more competitive and, as I mentioned before, competitive with the Japanese, Italians and the people from Iceland.

The geothermal industry R&D program also has an excellent record of technology transfer, not only in transferring technology from the laboratories and universities and developing new technology in industry, but it's also beneficial, the spinoff technologies that are appropriate to the oil and gas industry in particular.

Recently the Assistant Secretary for Fossil Energy, for example, asked Los Alamos National Laboratory and Sandia National Laboratory to form an oil recovery technology partnership which will transfer existing technology that has been developed mainly in the geothermal program, but also some in the fossil energy program to the oil and gas industry. That's one example. There is also the Geothermal Drilling Organization, which has 23 companies participating in five projects as well as the Geothermal Technology Organization.

If I can just focus briefly a moment on the hot dry rock program. In FY-89 we did a very complicated redrilling and completion of a damaged well that we have at our site in Fenton Hill. This now brings the well to full production and we are now currently preparing then to initiate a one-year long, what we call a long-term flow test. This test will provide the information on reservoir lifetime and thermal drawdown in total heat extraction capability that is important for industry to make in the form of investment decisions about this technology.

Unfortunately, we have not been able to progress on the test as quickly as we would like mainly because insufficient funds have been available to purchase the pumps and the additional surface equipment that are needed to run the test, and we're talking about a $2 million investment for the pumps and the surface equipment.

The success of our hot dry rock program has led to additional programs in the United Kingdom, Japan and the Soviet Union, all of which now are larger than the U.S. program. In addition, smaller programs are underway with France, the Germans and in Sweden as well.

Independent economic analyses by Bechtel, EPRI, Meridian Corporation, the United Kingdom and the Japanese, MITI, have all shown that hot dry rock has a potential for being economically competitive with other energy sources.

If I can go to the bottom line on the recommendations, the National Research Council recommended $35.7 million in FY-90 for the total geothermal program. Certainly with constrained Federal budgets, I would recommend something about half way between what is in the request and the NRC recommendation. Something on the order of $25 million would be appropriate. Within that request, we need $5.6 million for the hot dry rock program in order to initiate the long-term flow tests. The magma program should be increased to something on the order of about $5 million and then $1.5 million each for the Geothermal Drilling Organization and the Geothermal Technology Organization.

If I can move on just briefly on the fuel cells for transportation application programs. I am particularly pleased to report on the partnership we have formed with International Fuel Cells Corporation to carry out the research and development on a low-temperature fuel cell, which is particularly attractive for transportation applications, and this is called a proton exchange membrane, or PEM fuel cell.

It's a low-temperature fuel call and has the characteristic that it integrates thermally well with the fuel processing system or reformer as well as has the benefit of low temperature and being able to start quickly.

The fuel of choice for this is methanol, and the methanol was selected based on input from an advisory committee with members from the automotive industry as well as the petroleum industry. Chevron, for example, is a member of that.

Recognizing early on that industrial participation is important in the development of any new technology, and particularly if you develop low-cost manufacturing technology, we formed the partnership this current fiscal year with International Fuel Cells, and this partnership will ensure that the system design and manufacturing considerations will have a major impact in determining what the research goals are and the research requirements are and, in addition, it allows for our research results to be rapidly incorporated into fuel cell stack and system design.

Simply stated, Los Alamos carries out the basic research and technology development and International Fuel Cells performs the systems design and systems integration. Some call this tech transfer, but we think of it as a larger innovation cycle, and our Director, Dr. Sid Hecker I think testified before this Subcommittee last year on the innovation cycle.

Briefly again, there was another NRC report looking at electrochemistry, the electrochemistry program. They recommended $60 million for that program. Again, if you look at something about half way in between, you're looking at something on the order of $25 million for the electrochemical part of the energy storage program.

For the partnership in order for this to progress and to succeed, we are looking for something on the order of $8 million in FY-90, and I was asked to give some outyear numbers. So we are looking at $5 million in '91 and '92.

Again, this is an opportunity to develop an export opportunity, to help the automotive industry regain leadership in the world market, and we think this is an exciting technology that can have a major impact on our competitiveness.

I want to thank the Committee for the support in the past in both geothermal and the fuel cell program, and look forward to your support in the future.

[The prepared statement of Dr. Berger follows:]

STATEMENT

of

Michael E. Berger
Director
Energy and Technology Initiatives Office
Los Alamos National Laboratory

to

United States House of Representatives
Committee on Science, Space, and Technology
Subcommittee on Energy Research and Development

concerning

THE FUEL CELLS FOR TRANSPORTATION APPLICATIONS PROGRAM

March 2, 1989

The Fuel Cells for Transportation Applications Program
Discussed for This Statement is Funded by the
Office of Energy Storage and Distribution
U.S. Department of Energy

Thank you, Madame Chairman, for the opportunity to report on the progress of the Fuel Cells for Transportation Program and its potential impact on the national energy situation. I am pleased to report that significant advances have been made over the last two years that bring fuel cells much closer to the performance and cost requirements for transportation applications. In addition, I will report on a partnership formed in FY 1989 between Los Alamos National Laboratory and International Fuel Cells (IFC) Corporation to carry out research and development of Proton Exchange Membrane fuel cell technology for transportation applications.

Fuel cells are a potential alternative to internal combustion engines for transportation applications that may solve three critical problems: petroleum dependency, energy efficiency, and pollution. This potential arises from the fact that fuel cells chemically combine hydrogen and oxygen to produce electricity and water with very high efficiency. By using the electricity to drive an electric motor, a propulsion system with roughly twice the efficiency of an internal combustion engine can be produced. This means that much less energy would be required by fuel cell powered vehicles than by conventional vehicles. In the fuel cells for transportation applications program, the hydrogen used by the fuel cell is be carried in the form of methanol which can be derived from domestic resources including natural gas, coal, and biomass. The selection of methanol as the fuel of choice was based on the advice of experts from the automotive and transportation fuels industries.

The Los Alamos National Laboratory and International Fuel Cell Corporation Partnership

Recognizing that early industrial participation is important in the development of a new technology, and, in particular, it being crucial to the development of a low-cost manufacturing technology, we have formed a partnership between International Fuel Cells (IFC) Corporation, a subsidiary of United Technologies Corporation, and Los Alamos National Laboratory. IFC Corporation of South Windsor, Connecticut, is the largest fuel cell research, development, and manufacturing company in the U.S. The partnership will ensure that system design and manufacturing considerations have a major impact on determining the research requirements for the fuel cell components. In addition, research results obtained by Los Alamos can be readily used in fuel cell stack development and system design by IFC. This continual feedback loop is important in assuring that the fuel cell development of a cost effective fuel cell power plant for transportation applications is as efficient as possible. Simply stated, Los Alamos National Laboratory will use its unique capabilities and skills to perform the basic research and technology development for the fuel cell and fuel processor and IFC will use its experience in engineering, system design, and manufacturing to develop low-cost, reliable, high-power density power plants suitable for transportation applications. Some people call this process "technology transfer;" we prefer to think of this as part of a larger innovation cycle that optimizes the use of Federal funds.

The Need for Fuel Cells for Transportation Applications

The United States is rapidly increasing its dependence on foreign petroleum.

Current projections indicate that by the year 2000 over 60% of the petroleum used in the U.S. will be imported at a cost of nearly $270 billion per year. This makes the U.S. particularly vulnerable to foreign suppliers and contributes a huge amount to the trade deficit. Transportation currently consumes over 62% of the petroleum used in the country with highway vehicles accounting for over 75% of this consumption. Clearly, a change in the transportation sector is needed to solve this problem.

Carbon dioxide and its contribution to global warming is an increasing concern. Because of their efficiency, fuel cell vehicles would generate much less carbon dioxide per mile than conventional vehicles. Similarly, toxic emissions such as carbon monoxide and nitrous oxides are much lower from a low temperature fuel cell than from an internal combustion engine.

However, converting our transportation system to fuel cells is not easy and will require extensive research and development. The problem is that the technology is not yet proven or economic and needs continued government support to be brought to the point of successful commercial integration. The requirements for transportation applications are extremely stringent. The fuel cell must have sufficient power density to meet the performance specifications of the vehicle and fit within the available space. It must be sufficiently inexpensive to compete with internal combustion engines on an economic basis. It must be able to start rapidly and to respond quickly to changes in power demand. It must be safe and reliable. And it must tolerate the minute amount of carbon monoxide that is formed when methanol is processed to produce the hydrogen.

The Proton Exchange Membrane Fuel Cell Research Program

The most promising fuel cell technology for these criteria is based on solid polymer electrolytes. We call this technology the Proton Exchange Membrane (PEM) fuel cell. The solid polymer electrolyte is a plastic-like material that has excellent conductivity of protons when adequately saturated with water. It allows the fuel cell to operate at high-power density even at room temperature, and it facilitates the use of low cost materials and designs. To realize the potential of solid-polymer-electrolyte fuel cells for transportation applications, high-power density and efficiency must be achieved over a wide range of operating conditions; the costs of catalysts, membranes, and bipolar plates must be reduced; the impurities in the processed fuel must be accommodated or eliminated, and the elements of the propulsion system must be integrated. Once this is done, the system must be designed so that manufacturing and integration costs are minimized. This requires effort in three areas:

* Fuel cell component research,
* Fuel cell stack and fuel processor development,
* Fuel cell propulsion system design and integration, and
* Manufacturing process development.

To date, the majority of the research has been in the fuel cell component research area. Under sponsorship of the Department of Energy's Office of Energy Storage and Distribution, Los Alamos National Laboratory has made significant progress in this area. Over the past two years power densities have been increased a factor 4 (to 0.9 W/cm^2 of electrode area) in single cell tests on hydrogen and air. This was achieved with a platinum catalyst utilization of less than 0.8 gram per kilowatt. We have achieved more than a 40 fold reduction in platinum requirements per unit of power over the last 4 years. As a result of this research, the platinum is no longer a major cost factor in the cell. Problems with carbon monoxide poisoning of the catalyst when methanol fuel is used have also been dramatically reduced. By a combination of selective oxidation of the fuel and injection of small amounts of air into the fuel cell anode, the performance of the fuel cell can be restored nearly to the level achieved on pure hydrogen. These advances have overcome several of the technical obstacles to using fuel cells in transportation.

However, at the component level, further research and development is needed to:

- Optimize the fuel-cell-electrode composition and structure for high performance on low-pressure methanol reformate and air,
- Evaluate and further develop low-cost, solid-polymer-electrolyte membranes with high conductivity,
- Improve the control and understanding of membrane hydration over a wide range of operating conditions,
- Determine the effects of organic and inorganic impurities on cell performance and devise methods to lower deleterious impurity levels, and
- Evaluate and reduce the corrosion rates of supported catalysts and bipolar plate materials in the solid-polymer-electrolyte environment.
- Developing a compact, efficient fuel processor, or reformer, that can respond rapidly to changes in fuel demand while minimizing impurity content.

The advances made at the component level have and will set the stage for development of high-performance, solid-polymer-electrolyte fuel cell stacks. Based on single cell data, sustained power densities greater than 0.5 watt/cm^2 at high efficiency should be possible if the water management, heat removal, and gas flow are optimized. These objectives will require engineering development and concurrent design for system integration and consists of:

- Optimizing stack design and gas flow fields for operation on methanol reformate and air,
- Developing water management techniques to ensure proper membrane hydration, to prevent cathode flooding, and to collect product water that is needed by the fuel processor, and
- Developing an effective, low-cost heat removal strategy.

Achieving a high-performance, cost-effective, solid-polymer-electrolyte fuel cell stack technology specifically designed for transportation applications will require considerable engineering design, development and integration. In our joint program, IFC will:

- Complete testing of a PEM feasibility stack initiated in FY 1989 and modify the stack to incorporate improvements in performance and durability resulting from research conducted by Los Alamos,
- Prepare a conceptual design of a PEM power plant for automotive application using methanol as a fuel, including the development of performance specifications and definition of an integrated plan for basic research and engineering activities leading to a pre-prototype power plant test in FY 1993,
- Initiate the design and fabrication of a PEM stack reflecting the results of the conceptual design and corresponding Los Alamos research work of an automotive stack for test in FY 1991,
- Complete the fabrication and initiate the test of the PEM stack described above,
- Initiate the design and fabrication of a PEM breadboard accessory section for an automotive power plant, and
- Perform conceptual design studies integrating the Los Alamos and IFC PEM technology with renewable, solar, nuclear, and by-product gas concepts to mitigate power plant global warming, acid rain, and other environmental problems.

To insure effectiveness in this application, problems with fuel cell propulsion system integration also need to be addressed. The propulsion system must include the fuel cell stack, reformer, control system, and motor and drive train. The interaction of the system elements must be properly engineered to achieve a high level of performance. Important feedback to both the solid-polymer-electrolyte fuel cell stack development and the component research will result from the system integration effort.

Justification of Federal Support for the DOE Electrochemical Energy Storage Program and the Fuel Cells for Transportation Applications Program

The fuel cells for transportation applications program is funded by the Department of Energy's Electrochemical Energy Storage Program through the Office of Energy Storage and Distribution. The DOE Electrochemical Energy Storage Program is the only major applied electrochemical research and development effort aimed at domestic energy-storage markets. Its objectives are to develop and test advanced, high-performance, rechargeable batteries and low-temperature fuel cells to the point where transfer of the technology to industry is feasible. Shrinking budgets for the DOE's Electrochemical Storage Program have slowed progress or halted development on promising systems, and the scope of exploratory and supporting research efforts have been narrowed. The long-term impact of shrinking budgets is to greatly decrease the probability that a viable energy-storage technology will be available to cushion the inevitable future petroleum shortages, stimulate the U.S. economy, and improve the environment.

Leadership in energy storage technology presently resides in the U.S., Japan, and Western Europe. The focus of this nation's electrochemical energy storage R&D has been DOE's efforts to develop advanced energy storage, conversion, and fuel cell systems for electric vehicles and electric utilities. However, the U.S. does not enjoy a clear-cut superiority in this area, and in recent years we have been an importer of this technology. Enhanced Federal support will allow the United States to maintain its momentum to establish a firm competitive edge in energy storage, conversion, and low-temperature fuel cell technology. Long-range R&D on advanced systems for energy storage is a highly appropriate use of public funds because of the broad range of positive impacts that accrue to various national programs (nuclear, fossil and renewable energy) and national problems (dependence on foreign petroleum, the balance of trade deficits, and damage to the environment). The absence of existing markets for the eventual application of advanced storage and fuel cell systems makes long-range R&D a high-risk undertaking, which underscores the crucial need for continued government support. Because this program addresses vital national needs, offers tremendous benefits while requiring only a modest investment, includes a strong component of applied and basic research, it should be included with other high-priority national programs.

In 1987, Secretary Herrington released the Energy Security[1] report which noted that "... the United States and the world will, in time, come to rely largely on energy sources that are essentially inexhaustible, possibly including advanced nuclear fission reactors, fusion, and many diverse sources that are commonly lumped under the term 'renewable energy.' ... The combination of solar, wind geothermal, water, and biomass energy represents an extremely large resource base that, over the long-term, could become a major new source of energy supply... *The development of a technology base upon which industry can build will involve a sustained research commitment well in advance of potential payoffs. The Federal research program will continue to emphasize collaboration with industry in long-term, high-risk areas of technology-base development.*" The electrochemical energy storage program, and the fuel cells for transportation program certainly meet these emphasized requirements.

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[1] EnergySecurity, A Report to the President of the United States, March, 1987, U.S. Department of Energy, Washington, Dc, DOE/S-0057

Recommendations for the Energy Storage Program and the Fuel Cells for Transportation Applications Program

In 1987, a report by the National Research Council[2] recommended that the DOE Electrochemical Energy Storage Program not only continue to receive the support that has made possible the existing strong R&D effort, and which has involved major research institutions, including national laboratories, universities and industrial laboratories, but increase national funding for electrochemical research by $60 million per year. This recommendation is consistent with recent findings of Energy Research Advisory Board of the Department of Energy.[3] A DOE electrochemical storage research program consistent with these reports would be at a level of $25 million. This amount would provide funds adequate for exciting new research and development on the most promising candidate systems to the point of transfer of the technologies to industry.

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[2] "NewHorizons in Electrochemical Science and Technology," National Materials Advisory Board, Commission on Engineering and Technical Systems, National Research Council, Washington, DC, 1986.

[3] "Guidelines to the Department of Energy Long Term Energy Research and Development," Energy Research and Advisory Board, U. S. Department of Energy, Washington, DC, DOE/S-0041 through -0046, 1986.

In preparation of this statement, I was asked to provide a multiple-year funding plan that would protect the U.S. edge in PEM fuel cell technology. Consistent with this request, projected funding levels for FY 1990 and FY 1991 are given in the table below:

ACTIVITY AREA	Funding Required ($M)			
	FY90	FY91	FY92	TOTAL
Component Research and Development	2.0	2.0	2.0	6.0
Fuel Cell Stack and Fuel Processor Development and Propulsion System Integration	6.0	3.0	3.0	12.0
TOTAL FUNDING $M	8.0	5.0	5.0	18.0

The fuel cells for transportation applications program provides a distinct example where U.S. industry can seize and maintain the leadership opportunity for a potentially large, international technology. This technology will not only enhance energy and environmental security, it also will provide a competitive export opportunity for the U.S. automotive industry reducing the balance of payments, providing jobs and stabilizing the U.S. economy. We appreciate the support that this Subcommittee has given the program in the past, and look forward to your continued support in the future.

Thank you for the opportunity to be with you today. I will be happy to answer any questions.

Mrs. **Lloyd**. Thank you very much, Dr. Berger.

Dr. Kreitler, please proceed.

STATEMENT OF DR. CHARLES W. KREITLER, PRINCIPAL INVESTIGATOR, GEOPRESSURED/GEOTHERMAL, UNIVERSITY OF TEXAS

Dr. **Kreitler**. Thank you very much.

I am Charles Kreitler with the Bureau of Economic Geology, University of Texas at Austin.

Initially Dr. Myrin Dorfman, the Program Director of the Geopressured/Geothermal Program at the University of Texas had hoped to be here to make the presentation before this Committee. Dr. Dorfman presently is in the hospital undergoing surgery and apologizes for not being able to be here.

Mrs. **Lloyd**. We're happy you can be here.

Dr. **Kreitler**. Well, hopefully I can fill his shoes.

I think that Dr. Tarman has presented a very nice overview of the geopressured/geothermal program within the Gulf Coast that is sponsored by the Department of Energy, and in that context I don't want to repeat his testimony. You will see in reading his testimony and mine that they are really quite similar, but I would like to highlight a few points which I think are salient.

I think it's important to recognize that the geopressured/geothermal program within the Gulf Coast has been a two-phased program. One, it was initiated as an exploration and exploitation type program evaluating where the necessary reservoirs were, where the pressure reservoirs were and where the appropriate temperatures were located.

Once that was identified, then the Department of Energy then moved into a testing phase with a number of discovery wells or wells of opportunity, and these were oil wells that were bought or donated by the oil industry and a number of design wells were then used to test the resource.

We are now in that resource evaluation phase, and in many ways we are coming towards the end of that resource evaluation phase, but it's important to recognize that we are not at the end of that resource evaluation phase.

In the budget levels that are being recommended by the Administration, $2.9 million will essentially put the program at the end of the evaluation phase.

The Hulin well, a well which I think will represent the flag ship of the DOE program is a fascinating well, and I would like to just reiterate or comment on some of the elements within that because I think it offers a true potential that has yet to be tested in the Gulf Coast.

Recently the well has been cleaned and temperatures have been measured at 340 degrees Fahrenheit. They are estimated to be approximately 380. This is hotter than any of the other wells that have been used. In addition, there are pressures approaching 18,000 pounds per square inch. These are pressures that are higher than have been observed in any other of the test wells.

There is a possibility that there is free gas in this well, and at these pressures and temperatures it may well be that this gas is in a supercritical liquid phase rather than in a free gas phase.

This well has a fascinating potential for the geopressured/geothermal program, and again at the 2.9 level of funding by the Administration this well cannot be tested and, as Mr. Tarman had indicated previously, at the 2.9 level the work that can be done within the program is just to continue the testing at the Pleasant Bayou.

The Hulin well is again the flagship of the program, and at the level that it is being funded at, that well will not be tested.

What we will be able to accomplish, as we determined in a meeting this morning with the Department of Energy is that we will be able to test one sand for what we would call an intermediary flow test of approximately 90 days and that would be the extent of the testing. The well would then have to be shut in until a future time when the funding levels can be raised to be able to do the work that needs to be done there.

You raised a couple of questions to Mr. Tarman that I would like to offer a bit of an alternative answer to. I believe, Mr. Morrison, one, you're interested in whether industry had an interest in this program. We hope that with the Hulin well there will be an increased interest with industry. We are planning a workshop towards the end of the summer to develop an industrial associate program primarily with the oil industry to see whether we can get them to contribute to this.

We think the very high temperatures and the high pressures in this free gas that we may be seeing in the well will be an enticement for them to become more involved within this program.

You also asked whether the geopressured/geothermal resource was limited to the Gulf Coast. Not necessarily. Probably the major resource is there within the Gulf Coast, but there are also high pressured/high temperature fluids in many other parts of the United States, San Joaquin Valley, West Texas and a variety of other locations. And I mention this in the context that there is an interest here in whether these hot fluids can be used in EOR, an enhanced oil recovery of very heavy oils, and San Joaquin Valley is one area that is under consideration, or being investigated at this point, to see whether there is a possible mixing of the hot waters with the applicability of EOR.

Again, I would like to say that Dr. Tarman covered many of my comments in that context, and I don't think I want to bore you all with a repeat of them all.

I thank you for this opportunity to make my presentation.

[The prepared statement of Dr. Kreitler follows:]

Statement of

Charles W. Kreitler
The University of Texas at Austin

before

Committee on Science, Space and Technology
Subcommittee on Energy, Research and Development
U.S. House of Representatives

March 2, 1989

Ms. Chairman and Members:

I am Charles W. Kreitler, Research Scientist at the Bureau of Economic Geology, The University of Texas at Austin, and a Principal Investigator for the University of Texas' program on geopressured energy production from deep Gulf Coast sediments.

Geopressured-geothermal energy has long been recognized as an important energy resource for the United States. The U.S. Geological Survey has estimated the economically available thermal and methane resource to be between 100-1,000 quads. Research initially was oriented toward mapping the resource. More recently, efforts have been aimed at testing a set of wells designed specifically for the program and a set of wells of opportunity. The program is currently in this testing phase, a stage that is critical for determining the resource potential of geopressured-geothermal energy.

The major thrust of the program at present is the long-term flow testing of a deep (14,000 ft) test well (Pleasant Bayou well) southwest of Houston, Texas. The flow test is being conducted for a minimum of two years; we have completed approximately 3/4 of a year of testing. Pressure declines have been minor, indicating a large reservoir as had been previously predicted. Natural gas is extracted from the brine, and calculations of the thermal and pressure indicate that electric generation is possible. The Electric Power Research Institute will install a 1 megawatt hybrid power system on the well this year. We anticipate testing of this well to continue at least through the next year.

In addition to the test in Texas, a 20,000 ft deep well in southern Louisiana was donated by a private oil company, and has recently been reactivated by the Department of Energy for use as a very deep geopressured test well. This well, referred to as the DOE Hulin Test well, offers a unique opportunity to test deep geopressured-geothermal energy potential of the Gulf Coast sedimentary section. Preliminary measurements indicate bottom-hole pressures of approximately 18,000 psi and temperatures over 350°F. These are favorable conditions for efficient energy production. A two-year flow test is anticipated at the well. This test will provide confirmation as to the importance of the geopressured-geothermal energy resource of the Gulf Coast.

With the Hulin well, we anticipate that basic scientific discoveries of the deep continental crust of the Gulf Coast can be made. Research will probe into the origins of hydrocarbons, the origin of geopressures, and the role of brines from these deep sedimentary sections to act as the source for metallic ore deposits. Because of its great depth, high temperatures, and high pressures, the research potential from this well is unique to deep testing in the Gulf of Mexico region, as well as for most of the United States.

Important elements for the FY90 budget are to initiate the previously mentioned testing at the Hulin well, investigate the use of geopressured fluids for EOR of heavy oils, reenter the Gladys McCall well to conduct a post-flow test investigation of the reservoir after three years of flow testing, and continue testing of the Pleasant Bayou well.

Plans are being formulated to test if the hot waters from Texas Gulf Coast geopressured-geothermal wells can be used in enhanced recovery of heavy oils. Injection of the brines would lower the viscosity of the oils and increase production efficiency.

We need to evaluate the impact of long-term production on these deep geopressured reservoirs. The Gladys McCall well flowed for 3 years at approximately 20,000 barrels of brine per day. Investigating the physical and chemical changes of the rock reservoir will provide important information for future geothermal prospects, as well as conventional oil and gas production.

We recommend a research budget of 8.4 million dollars per year for 5 years for the U.S. Department of Energy's Geopressured-Geothermal program. The Department's recommended budget of 2.9 million dollars will provide only a minimum level of effort. To accomplish the goals addressed in this testimony, a budget of 8 million dollars per year is needed. These goals cannot be attained at this lower funding level. We believe this higher level of funding will provide long-term benefit to the Gulf Coast region by providing the best available testing of its geopressured-geothermal energy resource.

PANEL 3 DISCUSSION

Mrs. LLOYD. We thank you so much for being here, Dr. Kreitler, as well as Dr. Tarman to discuss this technology.

How long will it be would you predict, if you can't have adequate funding, before we have a technology to recover this energy on a commercial basis? What are we talking about here?

Dr. KREITLER. How long would it take?

Mrs. LLOYD. Yes.

Dr. KREITLER. Not to be flippant, but it would take as long as necessary to put the money back in the budget so you could do the testing. I mean the testing will not be done unless the money is in the budget.

Mrs. LLOYD. Before it would be commercially viable, before it would be economic for the private sector for using this technology.

Dr. KREITLER. There are a number of different ways in which the geopressured/geothermal research will be of value to the private sector. One is a better understanding of the deep subsurface of the Gulf of Mexico in increased oil and gas production and the possibility of electric generation.

Now in the context of electric generation, there will be a power plant located at the Pleasant Bayou well sometime this summer, but again I think that if the funding level is not increased, then that operation will run for about three or four months and they will shut that down.

Now what that means is that we will not have yet tested the electric generation capacity of geopressured/geothermal yet. Everything up to this date had been done on a conceptual basis, and the joint effort between EPRI and DOE is now such that the equipment is made and ready to go on line, and I presume that this same equipment would then go on line for long-term testing at the Hulin well.

Mrs. LLOYD. Do you predict sufficient evidence to formulate a model to predict energy recovery at other geopressured sites?

Dr. KREITLER. If the Hulin well turns out to be a successful well, whether the potential can be realized at the Hulin well, I think it offers up a lot more alternative areas to work with in the Gulf Coast. It would suggest that there is good permeability at depth within other locations. It's surprising to find these massive sands, and the Hulin well has approximately 500 feet of producible sand at a depth of close to 21,000 feet. This was not predicted, but it was found, and I think it would point to the oil industry that that type of permeability and temperatures are possible to be found at these great depths.

Mrs. LLOYD. How long has work been done on this technology?

Dr. KREITLER. Pardon?

Mrs. LLOYD. How many years has work been done on this technology?

Dr. KREITLER. On the geopressured/geothermal technology?

Mrs. LLOYD. Yes.

Dr. KREITLER. The program started in the mid-70's. In large part probably half of that time, about five or six years was devoted to the exploration, and it has been about five years that has gone into the testing, and I think the program has been in a decline for the last two or three years.

Mrs. **Lloyd**. Thank you very much.

Dr. Berger, would you compare for the record the state of our geothermal industry with other countries.

Dr. **Berger**. Yes, I would be glad to. The geothermal industry in this country, as I mentioned earlier, is suffering a little bit from basically low oil prices and natural gas that they view as a competitor.

We have about 2,000 megawatts on line in the geysers area, a lot of it brought by big companies such as Unocal, but other several smaller companies. These companies are all struggling financially, the smaller ones particularly, and the larger companies are moving offshore actually to the Philippines and Indonesia and Micronesia. It's more profitable to develop offshore than onshore.

What we find in some of our work, and we have a program funded by the Agency for International Development in Central America where we are doing mineral and energy assessments is that the countries that are the most aggressive and the most competitive are the Italians, the Iceland people, and I'm never sure if that is Icelanders or not and I try and avoid that, and the Japanese. The Japanese come in, and as we heard in the other technologies, they make no-interest loans and they get financial support from the government to be competitive, their government to be competitive and we just don't seem to work that way.

An example is in St. Lucia, where Los Alamos is part of the Caribbean initiative, they found a geothermal resource, they needed the electricity, they import oil diesel turbines to produce their electricity, and the award for drilling the well was actually a U.S. company, Big Chief Drilling out of Oklahoma City, but the power plant design and development all went to an Italian company, and this was done under UN development program funding.

Again, the Agency for International Development has tried to work with some of the companies and we are working with some of the U.S. companies to get them to be more competitive in the area, but low-interest loans are very tough to compete with, or no-interest loans.

Mrs. **Lloyd**. That's pretty hard to compete with.

Mr. Morrison.

Mr. **Morrison**. Dr. Berger, I have an understanding of geothermal representing Mount Saint Helens as one of our latest examples of runaway geothermal. [Laughter.]

I sit there and look at that ton of material throw out into the air for every man, woman and child on the face of the earth and wish we could cap that energy in some way, and I guess that's what you're working on.

Is there a depth that is relatively standard? How deep do we really have to go to get into these layers that really have effective energy sources?

Dr. **Berger**. There is no standard depth, and the way we measure is we look for what is called a geothermal gradient, and sort of an average is 30 degrees Centigrade per kilometer. To make geothermal really interesting, you need to get up in the couple hundred degrees Centigrade range to be very attractive, and so you can kind of work out the mathematics of what depths you're talking about.

On the West Coast and particularly in your area you don't have to go very deep, as you know, to find the very hot resource.

Other places, such as on the East Coast, one has to go deeper. At Fenton Hill, for example, in our program we are operating at a depth of about 12 to 14 thousand feet, and the temperatures are 300 to 350 degrees Centigrade. We are on the edge of an extinct volcano, although geologically speaking it's still volcanically active. The geothermal gradient there is quite high.

It really depends on which part of the country and what depth you have to operate in, but certainly in the geysers area you're talking about seven or eight thousand feet and sometimes a little deeper for a conventional hydrothermal resource.

Mr. **Morrison**. Is a difficult part of the technology the transfer of that heat then in a usable form to the earth's surface?

Dr. **Berger**. Well, there are actually several parts of the technology that are difficult, and it differs for each technology you're dealing with. Certainly in the magma where you're trying to extract heat out of magma is by far and away the most difficult.

The earliest difficulty was just having instruments, tools that you could put down a well that would work in these very hot, corrosive, severe environments, and a lot of research has been done on that at our laboratory, Sandia National Laboratories and many of the laboratories in universities and companies that have worked in that. As a result of that, we got tools that now are of use in the oil and gas industry because they are having to go deeper and into hotter environments.

The other one is drilling in a hot environment. It just wore out drill bits very early. The development of drilling muds that would work in these hot environments was another problem and the development of cements to complete wells in these hot, corrosive environments. So there have just been a lot of barriers, and we have managed through technology to reduce a lot of these barriers. Another barrier is the conversion, and it's fairly low temperature compared to fossil fuels, but you're talking conversion efficiencies on the order of 15 to 20 percent, and certainly improvements in conversion technology would have a big payoff.

Mr. **Morrison**. At what price per barrel of oil does geothermal really begin to shine?

Dr. **Berger**. Well, again, it depends on where you're at. In the geysers area I think if you start getting into $20 to $24 a barrel, which is not too far off where we're at now, it's very attractive in that area. There are other areas which are economically attractive, such as the Roosevelt Hot Springs area in Utah.

One of the unfortunate things, I guess if you want to look at it as such, is much of the resource lies near or around natural parks and wilderness areas. So basically industry is prohibited from going in and developing the resource.

Mr. **Morrison**. Thank you. That's very interesting. It's a tremendous energy source if we could just utilize it.

Dr. Kreitler, Lamar Smith who is a Member of this Subcommittee and a very active Member has got a conflict with another Subcommittee and of course he being from Texas is very interested in the geopressured/geothermal program which you and Dr. Tarman have described.

You had mentioned in your testimony something that I think he was pushing at. He wanted to know about the potential that these technologies have for assisting oil production, and I guess it's the potential of using the hot fluids to help bring some very heavy oils to the surface.

Dr. **Kreitler**. That is one of the areas of interest immediately now or in the forefront right now. There is a strong interest in the use of hot waters for dropping the viscosity of oils in enhanced oil recovery programs.

I think the geopressured/geothermal program, however, has been of great benefit to the oil industry in a variety of other fashions.

One of the early problems with the geopressured/geothermal program in producing brines on the order of 10,000 barrels per day were problems associated with scaling, that is the precipitation of minerals in the well itself causing a decrease in flow and this sort of thing.

In areas like that a great deal of research was done in developing inhibitors to prevent scale, and from that a new industry has evolved essentially through a gentleman by the name of Mason Thomson I believe at Rice University who is working now on associate programs with the oil industry to get around the scale problem that the entire industry faces.

A lot of technology in well production, well testing and all this sort of thing has been directly transferred over to the oil industry, and a lot of understanding on the origin of oil and natural gas has resulted from the geopressured/geothermal program which has been of benefit to the oil industry.

Mr. **Morrison**. You mentioned you had some meetings coming up, as I recall, with the industry to talk about perhaps industry participation.

Dr. **Kreitler**. Right. That will be hopefully in early September.

Mr. **Morrison**. And potentially from that we will get a better idea of how interested industry really is in the application in the near term of some of these technologies.

Dr. **Kreitler**. Right. I think the industry has not been warm to geopressured/geothermal, one, because of the decreased price of oil and gas, two, they think they can produce the energy of oil and gas at shallower depths than what you need to do with geothermal, and they haven't been impressed by the temperatures or the size of the reservoirs.

What are being shown now is that there are very large reservoirs and they are also finding some very high temperatures and/or finding this phenomena of free gas at great depth which was not anticipated, and we think that industry will become more interested in that.

Mr. **Morrison**. So this is another case where you recommend a modest investment because this is potentially a significant energy contributor to the country.

Dr. **Kreitler**. Right, we believe so, and we believe that the country has invested a reasonable amount of amount of money within this program and that we're at that threshold of being able to complete things, that we're in that stage of finalizing the testing at

Gladys McCall, that we're beginning testing on the Hulin well, which probably is the best well that has been made available to DOE for this sort of thing, and if you want to complete these type programs, then the funding needs to be there, and it will not be there in its present level.

Mr. **Morrison**. Thank you.

Thank you, Madam Chairman.

Mrs. **Lloyd**. Thank you very much, Mr. Morrison.

Thank you, gentlemen, for your testimony.

This concludes our DOE budget hearings. We will of course have markup on our bill towards the end of this month.

I not only want to thank the witnesses and our recorders that have worked diligently, but I would also like to thank our staff for the excellent job they have done in preparation for our hearings. We are well blessed with good staff for all of our hearings.

If there is no further business——

Mr. **Morrison**. Madam Chairman, just one question. From today's hearing came a suggestion that fits outside really of the budget parameters, but may be one that we shouldn't let pass, and that's in the area of hydrogen. I'm wondering if even just a letter signed by the Members of the Subcommittee, or however you would like to do it, asking the Department of Energy to consider a hydrogen initiative. I sense from what we have heard today that this is a rather fragmented program that is really failing to zero in on the potential of hydrogen.

Mrs. **Lloyd**. Your point is well taken, and you certainly have my blessing. We will pursue this among the Members, and we can have the staff draw up the letter to the Department as well.

Thank you, Mr. Morrison, for your excellent help in our hearings.

Frank Murray, our new Staff Director, we thank you and we're happy to have you here, and Nancy Jeffery and Kitty Rising did an excellent job.

If there is no further business, the Subcommittee stands adjourned.

[Whereupon, at 4:15 p.m., the Subcommittee adjourned, subject to the call of the Chair.]

APPENDIX 1: STATEMENTS FOR THE RECORD

FEBRUARY 28, 1989

PMAA
PETROLEUM MARKETERS ASSOCIATION OF AMERICA
1120 VERMONT AVE. NW • SUITE 1130 • WASHINGTON, DC 20005 • (202) 331-1198

February 17, 1989

The Honorable Marilyn Lloyd, Chairwoman
Subcommittee on Energy Research and Development
Committee on Science, Space and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Madame Chairwoman:

Enclosed is the prepared statement of the Petroleum Marketers Association of America (PMAA) in connection with the February 28 Subcommittee hearing on the Department of Energy's Conservation R&D Budget for FY90.

Also enclosed for reference by Staff is a copy of the Battelle Pacific Northwest Laboratory Program Plan (PNL-5896, September 1986) mentioned on page 2 of PMAA's statement. Please have your staff contact me or Mr. Al Cobb, PMAA Director of Legislative and Political Affairs, if we can be of any assistance. PMAA members very much appreciate your cooperation in this matter.

Sincerely,

Dick Cahoon

C. Richard Cahoon
Vice President for Policy

CRC/cb
Enclosures
cc: The Honorable Sid Morrison
Ranking Minority Member

PMAA
PETROLEUM MARKETERS ASSOCIATION OF AMERICA
1120 VERMONT AVE, NW • SUITE 1120 • WASHINGTON, DC 20005 • (202) 331-1198

Statement of C. Richard Cahoon
Advocating A
DOE Conservation R&D Program for Home Heating Oil
Before the February 28, 1989 Hearing of the
Subcommittee on Energy Research and Development
Committee on Science Space and Technology
United States House of Representatives

The Petroleum Marketers Association of America (PMAA) is a national federation of 43 state and regional trade associations representing almost 11,000 independent marketers of petroleum products, equipment and service. While most of these marketers are small businessmen, collectively they sell over three quarters of the home heating oil and half of the gasoline consumed in America today.

PMAA is extremely concerned over the totally inadequate funding for Oil Heat Research in the Department of Energy's proposed Conservation and Renewable Energy budget for Fiscal Year 1990. The new Administration has proposed to cut the $750,000 funding level approved by Congress for FY89 to only $200,000 for FY90. PMAA will show that the Oil Heat R&D program will provide such dramatic benefits to consumers and to the nation in terms of reduced oil usage that the program should receive a dramatic increase in funding. The combustion research program for oil heat equipment is an element of a key activity called Technology and Consumer Products, within DOE's Buildings and Community Systems Division.

R&D Benefits for Consumers

Federal research has been very beneficial to consumers of oil heat by providing greater options for conservation, thereby benefiting the nation as a whole. The oil heat program that was started in 1976 at Brookhaven National Laboratory is one of the most successful stories in federal research history.

With an R&D investment of less than $10 million, Brookhaven demonstrated, among other things, the success of the flame retention burner that has become the industry standard for new oil heating equipment. New flame retention equipment and retrofit devices for existing oil burning equipment were estimated to save consumers over 10 billion dollars through reduced oil usage by the end of the next decade. Additional improvements that have resulted from development or demonstration activities at Brookhaven include typical energy savings of 9%-10% for vent dampers and flue heat recovery systems used with hydronic oil boilers. Cumulative energy savings for improvements to high efficiency burners and boilers are expected to exceed another 7 billion dollars by the year 2000.

Reducing Unnecessary Oil Dependence Thru Focused R&D

In addition to providing fantastic savings to consumers by means of dramatic reductions in oil usage, additional R&D on oil heating systems can address the oil dependency issue that some groups are making so much noise about lately. While PMAA believes that the current and forecasted glut of crude oil significantly reduces any potential problems with oil dependence, there is no question that the focused R&D program for oil can make a major contribution toward reducing any unnecessary oil dependence.

PMAA strongly supports continuing the current research effort and believes that there are several *additional projects that should be undertaken by DOE in FY 90 that are equally as promising in terms of costs and benefits as the example of the flame retention burner.* These projects have been identified and are described in detail in a study by Battelle Pacific Northwest Laboratory (PNL-5896; September, 1986). Briefly, a total funding level of $3.8 million is required, with specific program recommendations in thousands as follows:

- Technology Transfer ($650):
  - Identify technical & institutional barriers to oil energy conservation.
  - Promote the use of DOE recognized energy conservation options thru symposia, workshops, and consumer information.
- Overcoming Equipment Efficiency Barriers:
  - High venting system losses. ($400)
  - Lack of durable heat exchanger materials. ($750)
  - Declining fuel quality; impacts on atomization and combustion. ($740)
  - Inadequate equipment operating and service diagnostics. ($930)
  - Poor system integration. ($330)

According to the Batelle Pacific Study, Appendix Table A.1, the estimated fuel savings for these programs could total as much as 39 billion dollars. Fuel savings estimates for the various program elements range between 5% and 32%. Estimated market penetration rates range from 5 to 50%. Based on annual fuel oil consumption of one quadrillion Btu, these projects are expected to save consumers as much or more than the retention head burner is saving. Estimates of the cumulative savings over 20 years for each program element range from $779 million to $12.6 billion.

Federal Role is Needed

Due to the non-monopoly operations of fuel oil marketers who compete freely with one another, a federal R&D role is needed for the oil heat industry, even more than for competing industries that benefit from strong federal participation in R&D. The federal R&D programs for other fuels augment the work of the Gas Research Institute and the Electric Power Research Institute, which are funded by hundreds of millions of dollars in surcharges on gas and electric rates that are approved by federal and state authorities.

By contrast, local oil heat marketers have no exclusive sales territories and no government approval or means to impose R&D surcharges. Major oil companies, which produce and refine oil products, do not accept responsibility for any R&D activities on behalf of equipment manufacturers or any end users, including space conditioning, automobiles or airplanes.

Most manufacturers of oil heat equipment also make gas and/or electric appliances. With a relatively smaller sales potential in oil, it is understandable that equipment manufacturers commit their limited resources to the gas and electric equipment that is the focus of the government and utility research efforts.

Therefore, it is up to the federal government to provide funding for Oil Heat R&D, in order to maximize conservation options to the 15 million U.S. homes that heat with oil. While PMAA does not subscribe to the view that energy supplies will dry up tomorrow, it would be wise to have a strong conservation program to reduce consumer energy demand for home heating oil by taking advantage of exceptionally high benefit/cost ratios for Oil Heat R&D.

Budget Limitations

PMAA supports efforts to lower the deficit through reductions in federal spending, and is not asking for additional budget authority. PMAA believes that DOE's $15 billion budget proposal is more than adequate for DOE to meet the needs of its various constituent publics, including oil heat.

Since 18% of American homes use oil heat, their needs for increased conservation options should be protected by the allocation of $3.8 million to be devoted exclusively to oil heat. After all, the federal government is devoting billions of dollars to competing sources of energy such as natural gas and electricity from coal and nuclear power.

PMAA agrees with DOE's national energy policy of balanced and mixed supplies, and PMAA encourages DOE to include the oil option in the energy supply picture, so that DOE funding is provided for oil as well as forms of energy in competition with oil for a share of the home heating market.

PMAA believes that if DOE is going to continue any R&D programs at all, then it is only fair to the millions of oil heating homeowners that a tiny slice of the R&D budget pie be allocated to Oil Heat R&D. PMAA urges the support of this Subcommittee to continue this Oil Heat program that has such an excellent and beneficial track record of reducing oil consumption and benefitting not only oil users, but the country as a whole.

Thank you for your consideration of heating oil marketers and consumers.

BOB LAWRENCE & ASSOCIATES
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The DOE Industrial Conservation Programs

Testimony Before the

Subcommittee on Energy Research and Development

Committee on Science, Space, and Technology

House of Representatives

February 28, 1989

Madame Chairman and Members of the Subcommittee. I am Dr. L. R. (Bob) Lawrence, Jr., President of Bob Lawrence and Associates, a Consulting firm located in Alexandria, Virginia with a client base consisting of high technology companies. I appreciate the opportunity to be here today to testify on the Department of Energy's Industrial Conservation programs. I am particularly honored to be able to discuss these programs due to their unique record of producing benefits in the national marketplace, even in a stringent budget environment.

The Industrial Conservation program is one of very few government programs carrying out commercially oriented R&D with a relatively near term thrust. Examining some recent statements about such programs:

a) **Richard Darman, Director of OMB**, in his confirmation hearings stated that the nation needed a higher percentage of government funded, commercially oriented, R&D.

b) **The Cuomo Commission report stated**: "Many people fear we are losing the race to innovate. The number of new patents issued to U.S. inventors fell 39 percent between 1966 and 1983. In 1987, nearly half of all the patents issued in the U.S. were given to residents of foreign countries, more than doubling their share over the last twenty years. Japanese inventors received more than one-third as many U.S. patents as did residents of the U.S. Since the 1970's, the U. S. has increasingly lagged behind its allies in civilian R&D. Currently, Japan spends 47 percent and Germany 32 percent more (as a percentage of GNP) than the U. S. on civilian R&D."

And further: "To remain leaders in commercial technology, we must significantly readjust the ratio between federal spending for defense R&D and spending for commercial R&D. At present, nearly three-fourths of all federally funded R&D is defense-related, preempting resources and skilled personnel. We can no longer sustain funding of research simply because it falls under the rubric of "defense". As much as possible, our dollar resources need to be spent in a way that enhances the nation's commercial competitiveness.

c) **The Report of the President's Commission on Industrial Competitiveness states:** "Technology propels our economy forward. Without doubt, it has been our strongest competitive advantage. Innovation has created whole new industries and the renewal of existing ones. State-of-the-art products have commanded premium prices in world markets, and technological advances have spurred productivity gains. Thus, America owes much of its standard of living to U.S. preeminence in technology."

And further: "Roughly half of the total R&D done in the United States is funded by the Federal Government, which spends most of its money (about two-thirds) on defense and space programs. And in those two areas, any commercial spillover is not a prime objective. Thus, when we look at what the United States spends on civilian R&D - areas of innovation from which we can reap the greatest commercial reward - we find ourselves behind both Germany and Japan."

These statements are in sharp contrast to the Spring of 1981 when ideologs within the new Administration were stating "Industry can do it themselves", and "If it's a good idea, industry will do it!" In the Spring of 1981, there was a desperate fight in which these same zealots attempted to eliminate the entire Energy Conservation program, and thanks to this Committee and dedicated members of Interior Appropriations, the program survived, albeit in substantially lower size. The Administration then, realizing the elimination battle could not be won, relegated the program to a position of benign neglect and continuing negative pressure until the present time.

It has only taken eight years of record trade deficits and record budget deficits for the Administration to realize that American Industry might be able to use a little help from the Federal Government. It continues to amaze me how long the educational process can be for Washington Administrations, and how the taxpayer always pays the tuition. It is heartening to see that the new Administration will return to fact-based logic as a basis for actions rather than "I believe, therefore I know".

Let us go a little further to see what has happened in the last eight years. With the preponderance of federal spending going into the Defense arena, especially in relation to R&D, there has been a shift in the focus of our brighter scientific and engineering minds to the Defense sector. At the same time, our "allies" (this is a war-related term having no relationship to economic competition) overseas focussed their attention on innovation in the consumer markets. As a result, lifestyle and standard of living increases are now based on foreign-made VCR's, foreign-made TV's, foreign made stereo equipment, foreign-made compact disc players, and foreign-made cellular telephones. Everyone is aware of the story on foreign-made automobiles. While our innovation has concentrated on Star-Wars concepts, and weaponry which is stored or parked on a tarmac, our foreign competition has innovated in products which can fit into 100 million American homes (often in multiple quantity). Is there really any question as to why our trade deficit remains high even though our dollar has substantially devalued? It is not enough to make something cheaper, you must also make something desirable.

In the negative Executive Branch environment of the last eight years, the civil servants of the Industrial Conservation program deserve a tremendous amount of credit for continuing in a beneficial fashion to the taxpayers. With political appointees at DOE who were clearly unsupportive of their programs, the continuing support of this Committee was essential in allowing these beneficial results to occur. From the March 1988 document, "Summary of Impacts, Industrial Energy Conservation", we find that since the inception of the program, numerous technologies developed by the Industrial Conservation program have been put into production and use. Among these are: Alternative Powered Hand Tools, Catalytic Distillation, Catalytic Reactors, Cement Classifiers, Cogeneration with Coal-Fired Steam Turbines, Cogeneration with Slow-Speed Diesels, Coil Coating, Computer Controlled Ovens, Cupola Stack Air Injection, Fluidized Bed Waste Heat Recovery Systems, Foam Finishing for Textiles, High Effectiveness Recuperators, High Temperature Burner Duct Recuperators, High Temperature Recuperators, Hyperfiltration for Textiles, Organic Rankine Cycle Bottoming Units, Pipe-Cross Reactors, Plating Waste Concentrators, and Slot Forge Furnaces. Units of these and other technologies have been installed and are operating accross the US. In addition to the above, over 31,500 High-Efficiency Welding Units, 69 Dye-Bath Reuse Units, and 12,000 Advanced Irrigation Systems are known to be operating; all developed under the Industrial Conservation Programs.

Table 1, from the above-referenced report, shows the energy savings impact of these completed technologies.

ENERGY SAVINGS IMPACT OF COMPLETED IP TECHNOLOGIES

Technology	Total Federal Cost ($ in Thousands)	Units Operating	Current Energy Savings Rate 10^{12} Btu/Yr	Cumulative Savings Through 1987 10^{12} Btu/Yr	Estimated Annual Energy Savings Year 2010 (10^{12} Btu/Yr)
Boiler Workshops	308	51	2.78	33.90	3.7
Catalytic Reactor	1,467	5	0.236	0.73	43.3
Cement Particle Size Classifier	583	32	0.94	1.69	11.1
Cogeneration-Coal-Fired Steam Turbine	1,386	5	2.27	5.75	**
Cogeneration-Slow Speed Diesel	11,428	4	1.93	9.61	171.0
Coil Coating	194	25	3.00	25.80	7.8
Computer Controller Oven	458	14	2.43	7.73	9.8
Cupola Stack Air Injection	935	0	0.00	0.08	**
Dye Bath Reuse	214	69	0.25	1.50	7.6
Energy Analysis & Diagn. Centers	9,240	2,081	13.50	59.80	11.5
FBWHRS (Fluidized Bed Waste Heat Recovery System)	2,000	1	***	0.03	39.6
Foam Finishing	1,100	*	1.46	8.39	4.9
Heat Exchanger-Dryer	611	2	0.075	0.51	**
High Efficiency Weld Unit	444	31,500	1.90	2.47	9.6
HTBDR (High-Temperature Burner Duct Recuperator)	2,000	1	0.017	0.012	42.9
Hyperfiltration - Textiles	636	3	0.08	0.14	112.0
Irrigation Systems	1,500	12,000	3.50	14.50	40.4
Nitrogen-Methanol Carburization	371	2,089	3.80	21.00	10.5
ORC Bottoming Unit	3,000	2	0.056	0.55	**
Pipe-Cross Reactor	1,177	10	0.17	2.21	5.4
Plating Waste Concentrator	442	7	0.066	0.07	10.8
Recuperators (Metallic)	1,500	57	0.49	4.20	15.2
Recuperators (Ceramic)	2,580	504	1.04	9.22	15.7
Slot Forge Furnace	2,436	21	0.46	3.47	88.1
TOTALS	45,960		40.44	213.86	660.9

---

* Represents 2.0 billion linear yards of broadwoven and knits and .53 billion square yards of carpets and rugs.

** Projections not available.

*** Unit restarted in January, 1988.

Table 1.

One hears the arguments "high-risk, long term R&D is the government's role", and "with the billions we are putting into long-term research, isn't that enough?" Unfortunately, the "long-term, high risk" terminology was used by political appointees to eliminate near-term, successful R&D programs, and to promulgate programs with missed milestones and negligible results. One can hope that, with the appointment of Admiral Watkins, the political appointee ranks of DOE may be filled with some instances of program management expertise and dedication to success rather than dedication to dismemberment. Unfortunately, high-risk, long-term R&D makes sense only if the entire transition route is accounted for; from basic research through product introduction. Where we have been generally failing in this country is in the 5-10 year period before commercialization. The recent Administration has felt that technologies which are 5-10 years from market introduction are close enough for industry to pick them up, and industry has generally felt that they need a 3-5 year return on investment, maximum, in order to make a major investment. By leaving this gap, the United States has successfully spent billions bringing technologies to the 5-10 year mark, leaving them for foreign competition to bring through the final transition phase, and then watching American industry try to play "catch-up" with the foreign competition which introduces the product or process. The 5-10 year time period must be addressed by cost-shared programs, R&D tax credits, low interest loans, or other incentives if we are to recapture the innovative product lead.

One of the reasons behind the Industrial Conservation Program's unique success is that it is a fully integrated program. By that, I mean it contains not only Research and Development, but also a strong Implementation and Deployment/Technology Transfer element establishing paths by which successful R&D may be implemented in the marketplace. Among the implementation processes is the highly successful Energy Analysis and Diagnostic Centers program administered by the University City Science Center in Philadelphia. As will be shown in other testimony before this Subcommittee, the EADC program has actually produced a substantial return on the government's investment by producing tax revenue greater than the cost of the program, through the profits resulting from the technology transfer and implementation.

As for recommended funding for the uniquely successful Industrial Conservation program, I would recommend a funding level of $55M, which is not a substantial increase, but which would begin the slow climb back to where the funding level should be for this program. Over the next three years, this program should be targeted to reach $110M, or about the same level as the Navy's Manufacturing Methods and Technology program. If we can spend that amount for just manufacturing improvements for one Defense arm, we can certainly spend it on behalf of Industrial R&D for our entire nation.

I thank you for the opportunity to testify before this Subcommittee.

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(215) 895-2322

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The Honorable Marilyn Lloyd
Chairman, Subcommittee on
Energy, Research and
Development
House Committee on Science,
Space and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Congresswoman Lloyd,

Enclosed is a copy of my testimony which I would like to have inserted into the record for the February 28 hearings conducted by the Subcommittee on Energy, Research and Development. I deeply appreciate your courtesy in including my testimony in that record.

Sincerely,

Frank Ko

Dr. Frank K. Ko
Director
Fibrous Materials Research Center

College of Business and Administration
College of Humanities and Social Sciences
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The Honorable Marilyn Lloyd
Chairman, Subcommittee on Energy, Research and Development
House Committee on Science, Space and Technology
United States House of Representatives
Washington, DC 20515

17 February 1989

CONTINUOUS CERAMIC FIBER COMPOSITES

Madam Chairman and members of the Subcommittee,

I deeply appreciate this opportunity to present written testimony regarding our interest in authorization for industrial development of Continuous Fiber Ceramic Composites. This program is currently being assessed by the Office of Industrial Programs under the DOE Assistant Secretary of Conservation and Renewable Energy.

For your background information, continuous ceramic fiber composites are a new class of engineering materials composed of a monolithic ceramic matrix and continuous monofilament and multifilament fibers. The development of the capability to process continuous ceramic fiber composites by the United States has critical implications for the nation's energy independence and has a far-reaching impact on the advanced product manufacturing capabilities of the nation.

Characterized by their noncorrosiveness and high temperature capability (well over 1000° C), continuous ceramic fiber composites are strong and tough materials which can be processed into a wide range of structural product shapes. These unique characteristics can be translated into highly energy-efficient and reliable machine components which enable the development of advanced processes and products. Since components fabricated using continuous ceramic fiber composites are able to operate under high-temperature conditions, the total energy savings in energy-intensive processes as are used in the manufacture of steel, pulp and paper have been estimated at well over 5 Quads! A substantial energy savings is also anticipated from continuous ceramic fiber composites in turbine components such as turbine rotors and in power generation such as in

College of Business and Administration
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College of Engineering • College of Science

catalytic combustors. Besides providing the enabling technology for energy efficient processes through continuous ceramic fiber composites, a large family of products ranging from fasteners, seals and surgical implants to laser mirrors is envisioned. The market size stimulated by continuous ceramic fiber composites in the free world is projected to be over $17 billion by the year 2000.

Considering the enormous economic potential for primary products and secondary benefits derived from continuous ceramic fiber composites, a tremendous effort has been undertaken by the developed nations such as Japan, France, and the United Kingdom

The most aggressive nation in these efforts is, unsurprisingly, Japan. According to a recent fact-finding study conducted by Professor Koczak of Drexel University and a group of American scientists* , after the successful completion of an eight year MITI Advanced Composite Materials Program (Jesedai Program) a major initiative had taken place in ceramic fiber composites in Japan. With a budget of over $145 million, the Japanese Fine Ceramic Centre (JFCC) was established in April of 1987 at Nagoya, dedicated exclusively to basic and applied ceramic research. The mission of the JFCC is to establish standardization of testing methods and promote cooperation between universities, government and industries in developing the necessary data base for ceramic matrix composites. With an already well-established leading position in continuous ceramic fiber manufacturing, the fine ceramics effort in Japan will undoubtedly propel Japanese industry into a very competitive position in high-performance structural ceramic matrix composites for years to come!

In Europe, France is clearly the leading challenger in continuous ceramic fiber composites. The licensing agreements reached in recent years between Societe' Europeen de Propulsion and du Pont; Aerospatiale and Hercules; and Brochier and Textron, representing a transfer of continuous ceramic fiber preform and composite manufacturing technologies from France to the United States, are cases in point. An ambitious program in continuous ceramic fiber composites is also taking shape in the U.K. with Rolls Royce, Ltd. developing composite turbine components.

Because of the obvious potential payoff, the global competition will be keen and, indeed, has already started! With the American ceramic fiber industry 10 years behind the Japanese and ceramic composite processing technology at least 5 years behind France, we can characterize the ceramic composite technology in America as being at the stage at which organic composites were 25 years ago. As we now know, substantial support for organic composites manufacturing research provided by the Department of Defense in the 1960's has resulted in our world leadership in organic composites. A similar effort for continuous ceramic fiber composites is both timely and necessary if the Department of Energy is to boost American competitiveness.

---

* M.J. Koczak, K. Prewo, A. Mortensen, S. Fischer, M. Barsoum and R. Gottschall, Inorganic Composite Materials in Japan- Status and Trends, a study sponsored by the Office of Naval Research, 1989

In summary, I would like to impress upon the Committee that the opportunities created by continuous ceramic fiber composites are enormously related to America's position in energy independence and economic superiority. I strongly urge your support of the Continuous Ceramic Fiber Composite Initiative.

Sincerely,

Frank Ko

Dr. Frank K. Ko
Associate Professor of
Materials Engineering
and Director, Fibrous
Materials Research
Center

American Council for an Energy-Efficient Economy

1001 CONNECTICUT AVE., N.W. SUITE 535 WASHINGTON, DC 20036 (202) 429-8873

MAR 16 1989

March 13, 1989

Representative Marilyn Lloyd
Chairwoman, Subcommittee on Energy
Research and Development
Committee on Science, Space and Technology
U.S. House of Representatives
B374 Rayburn
Washington, D.C. 20515

Dear Chairwoman:

During your subcommittee's hearing on energy conservation and renewable energy research and development on February 28 you requested additional information on two research initiatives I mentioned during my testimony. Enclosed are descriptions of the Urban Heat Islands research initiative and the Energy Labels for Window Units research initiative.

Our organization is very encouraged by the interest you are showing in energy conservation R&D. Your leadership in this area is critical to restoring some of the huge budget cuts this program suffered during the Reagan Administration.

Thank you again for inviting me to testify. Please let me know if I can be of further help.

Sincerely,

Marc Ledbetter

Marc Ledbetter
Senior Associate

Additional LBL Supported Initiatives

2. ENERGY LABELS FOR WINDOW UNITS

Laboratories: LBL, others?

Contacts: Steve Selkowitz (FTS 451-5605)

NEED / JUSTIFICATION FOR FEDERAL ROLE

A wide variety of new window technology options are available today and more will be available in the near future. Much of this development occurred in response to rising energy prices and a greater level of concern for occupant comfort and productivity. In principle, the availability of these new options provides more choice and design freedom. At the same time it requires more technical knowledge on the part of the specifier and puts greater stress on the network of computational and experimental procedures by which window properties are determined. As building codes and standards are upgraded on a state by state basis, they may over- or understate the capabilities of the new window technology. Inconsistent and confusing product data on new windows slows sales and market growth for manufacturers, and reduces energy savings for the homeowners and for the nation. Specifiers and purchasers of windows need a simple and accurate way to compare window properties and performance.

To be effective, labels should be: 1) technically accurate and meaningful; 2) simple to understand and use; 3) adopted on a broad national basis; and 4) implemented in a low cost, efficient manner.

The choice is not whether or not there should be labels for windows; there exist today dozens of different "labels" used to identify window performance. The problem with existing window labels is that there is no consistency to most of them and they therefore generate more confusion among users. Most have not been subject to impartial technical scrutiny to ascertain their accuracy. We lack a uniform, nationally based, accurate and validated labeling system.

CONCEPT / DESCRIPTION OF PROJECT

A window label should include data on **physical properties** (e.g. U value, visible transmittance, shading coefficient, air leakage, condensation resistance) and **energy performance** under assumed usage conditions. It might also include other parameters useful for selection if they can be adequately quantified, e.g. comfort, view, durability.

Physical properties are generally intrinsic to the window system although they may change with time as the window is used (or abused) and as it ages. Some of these values would be measured or calculated directly from a knowledge of the properties and dimensions of the window components (e.g. U value, S.C.) while others would probably only be measured (e.g. air leakage). The discussion above applies to "simple" windows comprised of sash/frame, and any number of glazings, coatings, and gas fills. Extending this to include shading systems with complex solar-optical properties is technically possible but significant additional research would first need to be completed.

Energy performance labels require that we already have data on standard physical properties. A label representing "relative" or nominal energy performance could be developed for prototypical building designs with standard operating assumptions, as a function of size, orientation and climate. The process by which such a label is developed might be complex and use state-of-the-art simulation tools, but the resultant end product could still be simple and easy to use. Energy performance labels might provide a uniform replacement for the hodge podge of different state code requirements for windows that exist today.

DEGREE OF IMPROVEMENT EXPECTED

Consistency across states and regions, and among state and federal agencies. Manufacturers would not be faced with developing different performance data for each sales region.

Consistency and comparability between products. Architects, engineers, specifiers and builders will be better able to understand the thermal performance differences between options offered by the same manufacturer and between products offered by different manufacturers. This may provide added confidence to specify higher performance products if the benefits can be reliably quantified with the label.

Alternative to, or supplement to, building codes and standards. Energy labels that have been derived from a sound technical base and have been validated with appropriate measured data might be used as an alternative to the current collection of different state building energy codes

Enhanced credibility for product performance claims. Relative energy savings claims implied by window energy labels should give specifiers and users added confidence to invest greater resources in products that provide better performance.

National labels developed in conjunction with non-commercial interests could provide reduced exposure to liability for manufacturers and specifiers. Labels developed using the best available technical data and with the active participation of non-commercial third party participants would be unlikely to be an inviting target for a lawsuit.

National Energy Efficiency. Reliable and accurate labels would enable window buyers to choose the most energy-efficient window products consistent with their use requirements, thus encouraging an optimal investment of consumer dollars in window energy efficiency.

EXPECTATION OF SUCCESS

The concept of a "label" to describe product performance is an old one that has been used successfully in many areas. Consumers today routinely use at least two energy related labels that seem to meet most of these requirements: auto fuel efficiency labels (miles-per-gallon) and appliance labels (relative annual operating cost). Windows are not as complex as either of those two precedents, and there is significant expertise in the testing and evaluation of windows and window components in both industry and the national laboratories. Further, there is support in the industry for a consistent set of performance labels. It seems clear that this project, while substantial, can be expected to be completed successfully.

EFFORT, DURATION, AND MILESTONES

Major Tasks:	1990	1991	1992	1993	1994	Total
Definition & Survey	200					200
Objective & Planning	200	100				300
Properties Labels	100	400				500
Energy Labels - Simple		200	400			600
Energy Labels - Complex			300	600		900
Demonstration & Education				200	300	500
	500	700	700	800	300	3000

Major Milestones:

1.	Definition of interest of all participants; Survey of existing/planned labeling programs; Relation to Canadian program	1990 - 3rd quarter
2.	Develop objectives for multi-year labeling program; Develop multi-year plan; develop industry/lab team; Identify organization to maintain/upgrade labels	1991 - 1st quarter
3.	Develop, test, and validate Thermal Properties labels - simple windows	1991 - 4th quarter
4.	Develop, test, and validate Energy labels - simple windows	1992 - 4th quarter
5.	Develop, test, and validate Energy labels - complex windows	1993 - 4th quarter
6.	Demonstration, Implementation, and Education	1994 - 4th quarter

BCS - NEW INITIATIVE
FY 1991

HI - 1

TITLE: URBAN HEAT ISLANDS REDUCTION

OBJECTIVE:

Summer temperatures in cities are typically 5-10°F higher than those in the surrounding countryside. These "heat islands" are growing in size and intensity. The temperature difference appears to be increasing about 1°F per decade in some cities.

The objective of this project is to obtain and disseminate quantitative data on cost-effective mitigation measures to reverse this summer urban heat island phenomenon and thereby save cooling energy, reduce peak electricity demand, and reduce carbon dioxide (CO_2) and other emissions from power plants.

JUSTIFICATION FOR FEDERAL ROLE (NEED):

Most heat island mitigation measures are elements of energy efficient urban landscape designs. For instance, trees shade houses and improve microclimate (wind and temperature) around them. Preliminary analyses suggest that major city-wide increases in tree coverage and changes in surface albedo (reflectance) of buildings and pavement can reduce peak cooling loads in many American cities by as much as 30%[illegible] This deliberate improvement of the man-made microclimate in urban areas translates into an annual potential savings of many billions of dollars of avoided investment in electric peak generating capacity and in avoided emission of CO_2. It also will provide major non-energy benefits in improved outdoor urban environments.

Land development processes are fragmented, and there is thus little incentive to invest in the development of techniques for new urban designs that reduce energy consumption. Cities and States to-date have not taken the initiative. The research needed is beyond the technical resources of cities. Implementation of the expected research implications requires crosscutting, multi-sector coordination. To realize the savings potential, a DOE initiative is appropriate, with cost sharing by utilities, State, and local governments and industry. The project would be coordinated with HUD, NASA and USDA.

EXPECTED IMPACT:

Direct effects of this new initiative, if widely implemented, involve substantial reductions in national energy consumption by 2010. The program will also help reduce energy-related environmental impacts (global warming, acid rain, and greenhouse effect, etc.). Specific program expectations include:

- More than $20B of avoided costs for electric generating capacity and building HVAC equipment.
- More than 0.65 quadrillion Btu's (0.65 Quad) of energy savings per year by 2010. = $4B/yr.
- About $4B savings per year to electric rate-payers.

HI-2

- Estimated 18M tons/year reduction of carbon as CO_2 emissions from power plants, plus capture of ambient CO_2, thus reducing urban and global warming trends.
- More than 10,000 to 1 rate of return on R&D, 50:1 on implementation.
- An effective way to help mitigate ever-increasing smog problems.
- High likelihood of implementation and success. The program involves measures that anyone can apply and that can be easily assimilated into the urban environment.

DESCRIPTION OF PROJECT:

This is a multiyear research effort that involves data gathering, modeling, verification of energy savings, and development and dissemination of implementation guidelines. The project phases are:

I. Heat Island Quantification

- Analysis of existing heat island data
- Measurement of microclimate variations within urban heat islands during the summer
- Development of algorithms to obtain heat island data from NASA's satellite and aerial data
- Numerical modeling of heat islands
- Cost assessment

II. Energy Savings Verification

- Simulation of energy and peak power savings, verification with utility load data
- Experimental scale modeling of strategies for heat island mitigation
- Field monitoring of demonstration projects for savings in consumption of cooling energy
- Assessment of high albedo materials

III. Global Warming and Environmental Effects

- Quantify heat island effect on smog
- Quantify the heat island contamination of global warming measurements
- Identify optimum CO_2 reduction measures through work with other agencies

IV. Implementation Guidelines

- Implementation strategies and model ordinance for heat island mitigation
- Guidebook for technical assistance to cities
- Develop recommendations for state, national, and international related policies

HI-3

RESOURCES REQUIRED:

Major Tasks	1991	1992	1993	1994	1995	Total
Heat Island Quantification	700	400	200	0	0	1,300
Energy Consumption Verification	100	700	800	300	0	1,900
Global Warming and Environmental Effects	200	450	450	500	0	1,600
Implementation Guidelines	0	300	500	800	1,100	2,700
Totals	1000	1,850	1,950	1,600	1,100	7,500

MAJOR MILESTONES AND EXPECTED DATE OF COMPLETION

1.	Completion of Heat Island Quantification	FY 1993
2.	Completion of Energy Savings Verification	FY 1994
3.	Completion of Analysis of Global Warming and Environmental Effects	FY 1994
4.	Completion of Field Testing and Implementation Plans	FY 1995

PUBLIC CITIZEN
Buyers Up □ Congress Watch □ Critical Mass □ Health Research Group □ Litigation Group

TESTIMONY

of

Nancy Rader
Energy Policy Analyst
Critical Mass Energy Project
Public Citizen

before the

Subcommittee on Energy Research & Development
Science, Space and Technology Committee
U.S. House of Representatives
Washington, DC 20515

March 2, 1989

215 Pennsylvania Ave. SE □ Washington, DC 20003 □ (202) 546-4996

Introduction and Summary

Public Citizen is a non-profit research and advocacy organization founded by Ralph Nader in 1971 to address a broad range of consumer and environmental issues. The Critical Mass Energy Project is Public Citizen's energy policy arm.

Public Citizen urges the subcommittee to support a substantially increased R&D budget for renewable energy technologies. Ideally, the budget should be increased to 1980 levels. However, in consideration of severe budget constraints, we urge the subcommittee to minimally support funding at 1985 levels.

Additionally, Public Citizen believes that a multi-year authorization bill is essential in order to restore stability to the renewable energy research program and to ensure its maximum efficiency. The authorization bill should direct the DOE to focus on the near-term commercialization of renewable technologies as well as long-term, high risk research in order to reap the benefits now of the technologies which are ready for the market, but which remain under-utilized. The bill to be introduced by Subcommittee Chair Marilyn Lloyd and Representative Philip Sharp would accomplish both of these goals, and we therefore endorse it wholeheartedly.

After energy efficiency, renewable energy sources offer the greatest near-term hope for reducing fossil-fuel-generated carbon dioxide emissions that are causing global warming. They also provide a domestic energy source which could realistically end U.S. dependence on foreign oil, as well as displace the need for nuclear power which has proven to be both expensive and dangerous. Renewable energy could accomplish these goals within 20 years if backed by a commitment from the federal government. This year's budget for renewable energy R&D can begin to put the U.S. back on that path from which it has strayed since 1981.

The following data is from Public Citizen's September 1988 report, Turning Down the Heat: Solutions to Global Warming. A copy of this report is on file with subcommittee staff. It also contains information that will be contained in an upcoming report by Public Citizen.

Renewable Energy Contributes Significantly to the Current U.S. Energy Supply

Renewable energy technologies have made significant advances in the last eight years, despite drastically reduced federal support for research and development. Most renewable technologies are now competitive with conventional supplies, and, together, they represent 9% to 10% of domestic energy production (depending on hydropower production levels), and 7.5% to 8.5% of total energy consumption in the U.S.

The Potential of Renewable Energy in 2000 and 2010

Public Citizen estimates that renewable technologies are likely to contribute 14 quads, or 15% to 20% of total U.S. energy consumption in the year 2000, depending on whether or not the U.S. increases the efficiency with which it uses energy. This estimate is conservative. What could actually be achieved is much greater, especially given a more favorable climate for development. Such a climate would include enhanced federal support for research and development programs.

Renewable energy could conceivably satisfy virtually all U.S. energy needs by the year 2010 if the government chooses to pursue that goal. According to a 1985 report of the DOE's own Energy Research Advisory Board (ERAB) and the DOE's 1985 Renewable Energy Research and Development Outlook, research advancements from some 43 technologies would allow renewable energy to achieve competitive viability in up to 80% of the national annual demand for energy in the year 2010. Further, total energy demand could be greatly reduced by that time if energy efficiency is promoted simultaneously with renewables.

Direct Link Between R&D and Potential Energy Supply

Government studies have shown that there is a direct link between federally-supported research on renewable energy technologies and the supply potential of those technologies.

The GAO reported in 1987 that the development of renewable technologies has been substantially hindered by drastically reduced federal R&D because the private sector does not compensate for DOE's reductions. As a result of the administration's policy, U.S. technology development has been delayed.

The ERAB report mentioned above recommended that the federal R&D program be maintained at then-current (1985) levels, emphasizing the importance of stable funding. The relative stability of the previous two years (1984 and 1985) permitted the DOE to "take steps in that direction," it said. Unfortunately, this stability did not continue, as the Reagan-Bush administration and Congress cut the renewable energy budget by another 50% since then.

ERAB's recommendation that funding be continued at 1985 levels was based on its presumption that there is a "long lead time before there is an urgent need for large supplies of energy from the renewable resource." This is no longer the case if the U.S. is seriously concerned about mitigating the effects of global warming. Thus, 1985 funding levels should be considered the minimum necessary.

The severe energy R&D cutbacks of the Reagan Administration--and now apparently those of the Bush Administration--reflect a "free market" approach to energy policy that shifted the emphasis of the renewable energy program away from near-term market development to long-range basic research of energy concepts.

The flaw in the Reagan/Bush approach is that it incorrectly assumes that renewable energy industries are capable of using basic research and applying it towards practical applications and commercial designs. This is not the case for solar industries because they are primarily composed of under-capitalized small businesses.

Further, it also overlooks the fact that the market cannot gauge the non-price benefits of renewable energy, such as their positive effect on the environment, human health, the economy, and national security.

Renewables Can Alleviate Global Warming

In our earlier report, we documented how a combination of renewable energy, energy efficiency, and natural gas have the potential to displace fully two-thirds of the carbon dioxide produced by coal and oil in the non-transportation sectors by 2000.

While renewable energy technologies now contribute about 6-7 quads of energy to the nation's energy supply, they are likely to contribute 14 quads in 2000. Assuming that renewable energy displaces all other sources of energy proportionately, one quad of energy displacement would reduce carbon dioxide emissions by about 75 million tons.

Based on this calculation, additional renewable energy supplies will displace at least 540 million tons of CO-2, or 8% of the total amount projected to be produced in 2000. This projection is based on the conservative estimate of what can be expected from renewable technologies, and not what could be accomplished with a more substantial R&D budget and other supportive public policies.

Renewable Energy Technologies Deserve Parity with Nuclear Power

It is peculiar that many promising and disparate renewable energy technologies are thought of as essentially one resource, and that they are funded at a combined level that is far lower than one, failing, technology--nuclear power. In 1989, nuclear energy fission and fusion programs (not including nuclear waste research and uranium enrichment losses) received over $700 million in comparison to total funding for renewables of less than $113 million.

Biomass energy alone is rapidly approaching an energy production level rivaling that of nuclear power. More importantly, many renewable energy technologies individually hold far greater promise than nuclear power for displacing fossil fuels causing global warming. Biomass energy, for example, could easily double by the year 2000 to 8 quads. Solar building technologies could increase manifold to displace up to 8 quads by 2000. It is difficult to imagine a utility ordering one new nuclear plant, let alone doubling nuclear capacity within 10 years.

Conclusion

Based upon the direct link between R&D and the potential supply of renewable energy, and upon the fact that developing renewable energy technologies must be an essential component of any strategy to reduce emissions causing global warming, we strongly urge the subcommittee to restore R&D funding minimally to 1985 levels.

Additionally, Public Citizen urges the subcommittee to support a multi-year authorization bill to restore stability to the renewable energy research program and to ensure its maximum efficiency. The authorization bill should direct the DOE to focus on the near-term commercialization of renewable technologies as well as long-term, high risk research so that renewable energy technologies that are now ready for the market can be properly utilized.

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DU PONT

E. I. DU PONT DE NEMOURS & COMPANY

FIBERS DEPARTMENT

MAPLE RUN BLDG.
P.O. BOX 80,721
WILMINGTON, DE 19880-0721

February 20, 1989

Honorable Marilyn Lloyd
Chairman, Subcommittee on Energy, Researach & Development
House Committee on Science, Space & Technology
U. S. House of Representatives
Washington, DC 20515

Dear Ms. Lloyd:

Enclosed is my testimony which I would like to have inserted in the record for the February 28 hearings conducted by the Subcommittee on Energy, Research and Development.

I appreciate your courtesy in including our testimony in that record.

Regards,

Glenn White

K. Glenn White
Business Development Manager - Ceramics

KGW:awn
Enc.

E. I. DU PONT DE NEMOURS & COMPANY

FIBERS DEPARTMENT

MAPLE RUN BLDG.
P.O. BOX 80,721
WILMINGTON, DE 19880-0721

Subcommittee on Energy, Research & Development
House Committee on Science, Space & Technology
U. S. House of Representatives

February 20, 1989

"CONTINUOUS FIBER CERAMIC COMPOSITE INITIATIVE"

Mr. Chairman, Members of the Subcommittee, I appreciate this opportunity to present written testimony regarding our interest in authorization for industrial development of Continuous Fiber Ceramic Composites. This program is currently being assessed by the Office of Industrial Programs under the DOE Assistant Secretary of Conservation and Renewable Energy.

E. I. duPont is active in the area of ceramic composites utilizing our organic fiber producing experience to develop and produce inorganic (ceramic) oxide fibers of alumina and alumina/zirconia. We also produce and commercially sell pitch carbon fibers from our Chattanooga, TN plant. These carbon fibers are used as reinforcements in various types of composites; i.e., polymeric, metal and ceramic. We are involved in three matrix technologies to produce the final composite:

1) Chemical Vapor-Infiltration (CVI)

2) "Lanxide" Directed Metal Oxidation Technology

3) Sol-gel

The development, evaluation and commercialization of advanced materials, i.e., ceramic composites, is an expensive, resource consuming and long process. The Japanese have established a leading position in the world in the area of monolithic ceramics (one phase - no reinforcement) and have initiated their adoption in automotive applications such as turbo charger rotors. Monolithic ceramics will satisfy a range of needs where a high degree of toughness is not required; however, in many, if not most, structural applications and high pressure, high temperature industrial uses, improved toughness is required. The toughness provides resistance to "catastrophic" failure and allows operability under high stress conditions. Composites provide increased toughness via incorporation of reinforcing materials such as continuous fibers, short chopped fibers, and whiskers (extremely small ceramic single crystals). Although the U.S. currently has an edge in the ceramic matrix composite field (reinforced vs. monolithic), increasing pressure from other countries is occurring. The Japanese have recently initiated joint government and industry programs to develop, evaluate and commercialize ceramic matrix composites using continuous fiber and whiskers as reinforcement phases (i.e., automotive ceramic gas turbine program). Much emphasis is also being given the development of standardization procedures and design methodology for advanced materials.

As an example, within MITI is the Agency for Industrial Science and Technology (AIST), which is charged with the task of creating new technologies for future industrial growth with a 1987 budget of about $1 billion. Also, a commitment of about $330 million has recently been announced for R&D in materials for engine development in supersonic and hypersonic aircraft. The U.S. advanced materials industry, specifically ceramics, needs authorization of development programs designed to maintain and improve our current competitive edge in the ceramic composite arena.

The United States Advanced Ceramic Association (USACA) is also initiating a "Bridging the Gap" project to obtain legislative and governmental support for policies that support and create a strong and viable domestic advanced ceramic industry. This project is consistent with the DOE Continuous Fiber Ceramic Composite Initiative. The USACA effort is supported by DuPont and other involved companies as one of the key efforts to maintain the U.S. leadership position in ceramic matrix composites and improve our position in monolithic ceramics.

DOW CORNING

February 22, 1989

The Honorable Marilyn Lloyd
Chairman, Subcommittee on Energy, Research and Development
House Committee on Science, Space and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Ms. Lloyd:

Enclosed is my testimony which I would like to have inserted into the record for the February 28, 1989 hearing conducted by the Subcommittee on Energy, Research and Development.

I appreciate your courtesy in including our testimony in that record.

Best regards,

James K Wessel

James K. Wessel
Director,
Cooperative Research and Development

JKW/ld
Enclosure

DOW CORNING CORPORATION, SUITE 325 SOUTH 1800 M STREET N.W., WASHINGTON, D.C. 20036 Telephone (202) 785-0585

TO: The Subcommittee on Energy Research and Development of the House Committee on Science, Space and Technology

DATE: February 22, 1989

TITLE: Continuous Fiber Ceramic Composite Initiative

Madame Chairman, Members of the Subcommittee, I appreciate this opportunity to present written testimony regarding our interest in appropriation for industrial development of continuous fiber ceramic composites. This program is currently being assessed by the Office of Industrial Programs under the DOE Assistant Secretary of Conservation and Renewable Energy.

"New structural materials will be a determining factor in the global competitiveness of U.S. manufacturing industries in the 1990's and beyond." This is the opening sentence in the Office of Technology Assessments' June 1988 report summary entitled, "Advanced Materials by Design". This assessment was in response to a joint request from the House Committee on Science, Space and Technology and the Senate Committee on Commerce, Science and Transportation. The assessment recommended the facilitation of government-industry-university collaboration in R&D. We support this recommendation. Besides international competitiveness, anticipated benefits include: energy conservation; reduced emissions and economic advantages.

Advanced materials can be classified as metals, ceramics, polymers, or composites, which generally consists of fibers of one material held together by a matrix of a second material. Composites are designed so that the fibers provide strength, stiffness and fracture toughness and the matrix binds the fiber together in the proper orientation. We are concerned with the research, development and manufacture of ceramic fiber reinforced products.

These products offer exceptional thermal stability and we anticipate their use in high temperature applications such as heat engine components, heat exchanger components and a broad variety of other high temperature products for high temperature applications.

DOW CORNING CORPORATION, SUITE 325 SOUTH, 1800 M STREET N.W., WASHINGTON, D.C. 20036 Telephone (202) 785-0585

Benefits include energy conservation (heat engines and industrial processes are more efficient at higher temperatures), reduced emissions due to improved efficiencies, and economic advantages (jobs and income). The economic benefit is substantial. The current value of the U.S. produced advanced ceramic composites is less than $2 billion per year. This will increase to $4 - 7 billion by the year 2000. In addition, non-U.S. markets are anticipated to be $10 - 13 billion by then. We also have the opportunity to get and maintain an international competitive lead if we establish a coordinated R&D plan with the major manufacturing companies as participants. This was not done previously with ceramics for electronic packaging, and the U.S. is now a minor supplier with Japan dominating this market.

We urge you to support a coordinated program between government, industry and academia, national in scope, to accelerate product and process research and development of continuous ceramic fiber reinforced materials in order to realize the above benefits. The details are being assembled by a industry/university ad hoc group. This will be presented to you as soon as it is available. We would be glad to provide additional information at your convenience.

Respectfully submitted
by
James K. Wessel
Director,
Cooperative Research and Development
Dow Corning Corporation

References: OTA report entitled, "Advanced Materials by Design", June 1988, Library of Congress Catalog no. 87-619860. "A Competitive Assessment of the U.S. Advanced Ceramics Industry", March 1984, Department of Commerce, NTIS Accession no. PB84-162288.

Babcock & Wilcox

a McDermott company

Contract Research Division

1735 I Street, NW
Suite 814
Washington, DC 20006
(202) 296-0390

February 22, 1989

Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy, Research & Development
House Committee on Science, Space and Technology
U. S. House of Representatives
Washington, DC 20515

Dear Ms. Lloyd:

Enclosed is testimony regarding appropriations to DOE for the development of "Continuous Fiber Ceramic Composites," which Babcock & Wilcox would like to have introduced into the record for the Energy Research and Development Subcommittee.

We appreciate this opportunity and we will provide additional information if requested.

Sincerely,

BABCOCK & WILCOX
a McDermott company

William G. Long

William G. Long
Manager, Ceramics

jg

Encl.

TESTIMONY TO THE
SUBCOMMITTEE ON ENERGY, RESEARCH & DEVELOPMENT
OF THE
HOUSE COMMITTEE ON SCIENCE, SPACE & TECHNOLOGY

February 22, 1989

"CONTINUOUS FIBER CERAMIC COMPOSITE INITIATIVE"

Mr. Chairman, we appreciate this opportunity to present written testimony in support of the development of a new class of structural materials, ceramic composites. We specifically request that an additional appropriation of $4 million be provided to the Office of Industrial Programs within the Department of Energy in the FY90 budget as the first step in a sustained commitment to establish a U.S. technology base in ceramic composites.

The United States has forfeit a preemptive position in manufacturing traditional ceramics to the Japanese. Japan has recently announced an $80 million eight-year effort to develop fiber reinforced ceramic composites. Unless the United States acts decisively, the technical lead we now enjoy in ceramic composites will be dissipated.

Over the past two months, representatives of United States industrial firms have met to discuss the need for a large congressionally supported effort to fully develop fiber reinforced ceramic composites. These meetings, involving many of the companies currently involved in the development of ceramic composites, have focused on the need for a multi-year program involving industry, universities, and national laboratories working in concert to bring ceramic composites to maturity. An outline of a program is evolving which would assure United States competitiveness in high temperature structural materials. These companies intend to continue their support for a comprehensive congressionally funded program on the development of ceramic composites.

CERAMIC COMPOSITES

Ceramics are non-metallic systems that are thermally and chemically stable at temperatures exceeding 3000F, whereas metals and alloys are limited to service temperatures below 1800F. However, ceramics fail in a brittle fashion, which limits their structural usage, while metals exhibit ductility and toughness distinguishing them as excellent structural materials. Composites are a general class of materials that can be defined as the sophisticated combination of two or more distinguishable materials. Composites have more desirable properties than their individual constituents. Thus, a ceramic composite, where the ceramic material is modified by the addition of fibers that add toughness will resist high temperatures and harsh environments, but will not suffer from the brittleness that makes monolithic ceramics poor structural materials. These materials are, however, in their infancy. A comprehensive, well organized effort is required to bring these materials to maturity.

WHY CERAMIC COMPOSITES ARE IMPORTANT TO U.S. ENERGY EFFICIENCY

The efficiency of engines and electric power generating plants improves as the operating temperature is increased. Higher efficiency means less fuel consumption and cheaper energy. For example, increased efficiencies of 10-30% are possible in power generation facilities through the use of ceramic composite air heaters. Other applications with similar benefits include industrial turbines, chemical processing, and steel processing. Such advanced systems, because of higher operating temperatures which exceed the limits of metals, demand advanced materials like fiber reinforced ceramic composites. Total energy savings for these industries could exceed 0.5 quads/yr.

An additional benefit from the use of ceramic composites is reduced dependence on strategic elements. Metal alloys require strategic elements like chromium and cobalt that come mainly from unstable foreign sources. Ceramic composites utilize elements like silicon, aluminum, and carbon, which are readily available. Clearly, ceramic composites are an enabling technology that can free U.S. industry from foreign dependence.

The U.S. is not alone in recognizing the importance of this technology. The Japanese have launched a concerted effort to develop ceramic composites, to complement their superiority in monolithic ceramics. Today the U.S. is ahead. However, if we do not aggressively pursue this technology and they do, the results will be very severe for U.S. industry. Since composites are generally tailored to a specific application (that is they go from raw material to processed shape in a continuous step), they will not be available as commodity materials in the world market as are steel ingots. Without the development of ceramic composite processing capability, high efficiency industrial systems will not develop.

The recommended program is a $100-million dollar effort involving multiple firms. This program will include process development with support from disciplines in fracture mechanics, non-destructive testing and interfacial micro-analysis. The process development would address major issues such as ceramic fiber development, fiber-matrix interface control, and matrix deposition. The combination of industry, national laboratories, and universities will provide a solid base to promote industrial usage.

SUMMARY

To summarize, B&W believes that ceramic composites will be the next major advance in structural materials. At maturity this will enable the design and construction of advanced engines, power generation equipment, and chemical processes operating at temperatures beyond the reach of today's materials. The higher operating temperatures of these advance systems will in turn mean higher efficiencies for these industries and give them a real advantage in world competition.

The development of ceramic composites is a major technical challenge. This challenge requires and deserves the unified, concerted efforts of U.S. industry, national laboratories, and universities. Furthermore, the Federal Government should co-fund this effort and serve as its integrator. We believe that the proposed program can succeed and we request your support for this program.

GEORGIA TECH RESEARCH INSTITUTE
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

GTRI

FEB 27 1989

February 20, 1989

Honorable Marilyn Lloyd
Chairperson - Subcommittee on Energy, Research and Development
House Committee on Science, Space and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Ms. Lloyd:

Please find the enclosed testimony which I request be inserted in the record for the February 28 hearings conducted by the Subcommittee on Energy, Research and Development. I appreciate your courtesy in including this testimony in that record.

Sincerely yours,

W. J. Lackey

W. J. Lackey
Principal Research Scientist
Energy and Materials
Sciences Laboratory

WJL:rdt

Georgia Institute of Technology is an equal education/employment opportunity institution of the University System of Georgia

GEORGIA TECH RESEARCH INSTITUTE
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

GTRI

February 20, 1989

Subcommittee on Energy, Research and Development

Committee on Science, Space and Technology

Continuous Fiber Ceramic Composite Initiative

Mr. Chairman, Members of the Subcommittee, I value this opportunity to submit written testimony regarding authorization for development of Continuous Fiber Ceramic Composites. Such a program is currently being assessed by the Office of Industrial Programs under the Department of Energy Assistant Secretary of Conservation and Renewable Energy.

Development of fiber reinforced ceramic composites is vitally important to the long term interest of the U.S. Such materials are capable of performing as structural members in very high temperature environments and thus their use in engines, heat exchangers, filters, etc. will permit more efficient, cleaner generation and use of energy. These materials will also permit non energy producing processes, e.g. steel making, to be performed more efficiently. For such reasons, development of fiber reinforced ceramic composites has been recognized by many, including Georgia Tech, as an important thrust area.

The DOE assessment of development of continuous fiber ceramic composites is particularly important since this fills a major gap in current U.S. technology. Efforts to develop composites for specific aerospace applications will not result, in my opinion, in adequate materials or processes for industrial applications. Also, recent work within DOE emphasizes short fiber and whisker (very small fibers) reinforcement - i.e., development of continuous fiber ceramic composites is not being pursued with sufficient vigor. The program under consideration by DOE would fill this gap.

Your consideration of this testimony is appreciated. Additional information could be provided if desired.

Sincerely yours,

W. J. Lackey

W. J. Lackey
Principal Research Scientist
Energy and Materials
Sciences Laboratory

Georgia Institute of Technology is an equal education/employment opportunity institution of the University System of Georgia

New Cogeneration And District Cooling Technologies For Meeting The Challenges of Global Warming, Atmospheric Ozone Depletion, Acid Rain and Local Air Pollution

Testimony before:
Energy Research and Development Subcommittee
Science, Space and Development Subcommittee
U.S. House of Representatives

Testimony on:
Proposed New Initiative For FY 1990 DOE District Heating and Cooling Program Budget

Testimony by:
Robert O. Couch
President
International District Heating and Cooling Association
Washington, D.C.

Abstract

The International District Heating and Cooling Association (IDHCA) has formulated and herein proposes to the U.S. Congress a new technology research and development initiative for the DOE's District Heating and Cooling Program. This new initiative focuses on those advanced cogeneration and district cooling technologies which can contribute significantly to resolving the interrelated environmental problems of global warming, atmospheric ozone depletion, acid rain and local air pollution. If the significant potential of advanced cogeneration and district cooling technologies for alleviating these environmental crises is to be tapped, funding for the DOE District Heating and Cooling Program will have to be increased from presently inadequate levels of $0.9m in FY 1989 to $5m in FY 1990. Expenditures at this level will, in the near term (4-5 years), make commercially available a number of advanced cogeneration and district cooling systems which can begin to have an immediate and substantive impact on the environmental crises presently confronting our nation and the world.

Advanced Cogeneration and Heat-Activated Cooling Technology R&D

Over the last 6 years since the Public Utilities Regulatory Powers Act (PURPA) was unanimously upheld by the Supreme Court 20,000 MW of cogeneration capacity has been installed in the United States. Although cogeneration accounts for only 3.5% of total U.S. electric generating capacity, many estimates indicate that cogeneration's market potential is somewhere in the range of 50,000 to 93,000 MW of electrical generating capacity. Most of the cogeneration capacity developed over the last 6 years has been installed in the industrial sector. Only about 100 MW have been installed in the form of "packaged cogeneration systems" in the buildings sector, i.e. commercial, residential and institutional buildings. Yet, most estimates of the market potential for cogeneration in the U.S. have indicated that the buildings sector holds at least as much promise as the industrial sector, perhaps as much as 25,000 to 46,500 MW.

The ability of building sector cogeneration to achieve dramatic energy savings as well as a number of critical environmental benefits should not be underestimated. Compared with conventional systems, i.e. condensing utility power plants with generating efficiencies (including transmission losses) of 30% and an in-plant heat-only boiler operating at 80% efficiency, an advanced natural gas fired diesel engine cogeneration system generates electricity at 42% efficiency, recovers heat at 48% efficiency, exhibits an overall energy efficiency of 90% and thus obtains an efficiency advantage of 50% over the conventional alternative.

In the cooling mode the advantages can be even greater. When a cogeneration system (37% efficiency) is combined with a high efficiency ammonia chiller (COP 6.0) and a double effect absorption chiller (COP 1.0) for an overall COP of 2.7, an impressive energy efficiency advantage of at least 38% over the conventional alternative is achieved since the conventional system's efficiency only achieves an overall maximum system COP of 1.75 after electrical generation, transmission and utilization efficiencies in a state-of-the-art electric chiller are accounted for. If the cogeneration-chiller system is compared with average electric building chillers with an overall system COP of 1.0, then the efficiency advantage is as much as 60% over the conventional alternative.

In addition, advanced gas fired diesel engine cogenerators employing ammonia chillers and lithium bromide absorption chillers do not use chlorofluorocarbon (CFC) refrigerants which are responsible for atmospheric ozone depletion when released into the air. Such systems offer an alternative to the use of substitute "drop-in" refrigerants, the use of which is accompanied with an efficiency penalty of as much as 20%. Building codes prohibit the use of ammonia refrigeration systems inside non-industrial buildings due to the possible toxic effects of the gas if ever released in large amounts in a confined space with people present and unable to escape in a short time. However, ammonia can be used outside buildings under the controlled conditions of a central cogeneration and district cooling plant and in this manner can be used to substitute for building chillers using CFC's. Thus, advanced cogeneration, non-CFC absorption and ammonia chillers and district cooling can achieve dramatic increases in energy efficiency and reductions in carbon dioxide emissions while substituting environmentally benign refrigerants for CFC. These systems offer the prospect of a cost effective, market driven approach to simultaneously alleviating global warming by reducing carbon dioxide emissions and atmospheric ozone depletion through the use of environmentally benign refrigerants.

A recent report on the subject of "Modular Cogeneration In District Heating and Cooling Systems", completed by Brookhaven National Laboratory for DOE's Office of Buildings and Community Systems concluded that a number of technical opportunities exist to correct the deficiencies in commercially available cogeneration systems and thereby speed the introduction of cogeneration into the buildings sector. The highest priority R&D projects identified were as follows:

- Heat-activated cooling technology for use with small to intermediately scaled (100kw to 1MW) gas and oil fired diesel engine cogeneration systems:
  - Double effect absorption chiller of American design and manufacture for use in gas fired diesel engines with a coefficient of performance (COP) of 1.2;
  - Triple effect absorption chiller with a COP of 2.0, the theoretical basis of which has been established by Oak Ridge National Laboratory;
  - Jet refrigeration technology (COP 0.6 to 0.8) which offers a low cost solution for intermittent building cooling loads as well as possible automotive air conditioning applications; and
  - Bottoming cycle turbines which can boost cogeneration electrical generation efficiencies by 3 to 4%.
- Reduction of emissions from gas and/or oil fired diesel engine cogeneration systems:
  - Reduction of nitrous oxide emissions using water injection technology.

The proposed level of funding for FY 1990 for cogeneration technology for application in district cooling systems is $1.0m.

Advanced District Cooling Technology

The next most significant high priority area for R&D is in advanced district cooling technology which is necessary to link cogeneration systems with building loads. District heating and/or cooling is a thermal distribution technology comprising a network of hot or chilled water pipes distributing space heating or air conditioning to a number of buildings. District heating and cooling is also a means by which energy sources and energy conversion processes which cannot be employed in a single building for supplying heating, cooling and electricity can be supplied to groups of buildings by centralizing the energy conversion facilities and removing them from the confines of a single building.

District heating has been extensively applied in many European countries many of which supply over half of their buildings with space heating from district heating systems. As a result, several European countries have much greater levels of cogeneration capacity serving their building sectors than the U.S.

Unlike European buildings, most American buildings of moderate to large size require air conditioning which could be supplied with advanced cogeneration and district cooling technology. However, district cooling is a relatively immature technology with substantial room for technological improvement to reduce costs and increase efficiency. The lack of efficient, low cost district cooling technology is a major impediment to the development of cogeneration for buildings since these systems assemble the thermal loads of many buildings to facilitate the economical sizing and operation of cogeneration systems. The availability of advanced district cooling technology will also enable cogeneration systems to take advantage of the load diversity factor characterizing aggregated thermal loads which produces relatively flat load curves looking very much like the heat load curves of industrial plants which tend to be relatively constant, permitting the cogeneration system to achieve a relatively high utilization of its capacity and a much more rapid payback than if it had to respond to typical single building thermal load curves which are dominated by peaks.

The research and development tasks which need to be accomplished in the near term to make advanced district cooling technology commercially available focus on the development of advanced transmission fluids. These fluids include phase change materials including ice slurries and friction reduction additives. As the accompanying figure indicates, advanced DHC transmission fluids will have a critical impact on the capital and installation costs of DHC piping systems which can comprise 50-75% of the cost of a DHC system. Such dramatic cost reductions can only accelerate the penetration of cogeneration into the buildings sector.

The following technology R&D projects in advanced fluids and ice slurries have been designated as highest priority and are essential to the development of cost effective advanced district cooling technology:

- -- Advanced Fluids
    - -- Polymer and fiber friction reduction additives for use in district cooling systems;
    - -- Surfactants for friction reduction in district cooling systems;
    - -- Heat transfer enhancement; and
    - -- Combined friction reduction/heat transfer enhancement.
- -- Ice Slurries
    - -- Ice slurry evaporator development;
    - -- Direct freeze ice slurry system testing;
    - -- Ice slurry loading and heat transfer; and
    - -- Influence of ice slurry crystal size on hydraulic behavior.

The proposed level of funding for the new initiative in district cooling technology R&D is $1.0m.

Advanced Component R&D For District Heating and Cooling Systems

Scientific and technical advances in a number of fields have stimulated the development of new advanced components of various types for use in either upgrading the performance of existing DHC systems or for incorporation into new system designs. Each of the advanced components under development contribute in some significant way to DHC system performance. For example, vacuum steam radiators can convert district heat delivered to a building in the form of hot water to steam at temperatures well under the boiling point of water (100 degrees C/212 degrees F) by using vacuum pumping technology which creates a partial vacuum or subatmospheric pressure in a radiator. This permits buildings heated with steam to be supplied by new hot water district heating systems, a far more economical option than supply by costly and inefficient steam district heating. Since most older buildings located in the central cities of the northeast and midwest are heated by steam, this one project could have the effect of opening up a huge new market for hot water district heating technology which was previously closed to it.

In the area of advanced components for DHC, the development of the following high priority projects have been stalled due to lack of funding. Development will be continued in FY 1990 if sufficient funding is appropriated.

- Vacuum steam radiator proof of concept testing;
- Open cycle heat pump proof of concept testing;
- Advanced rankine cycle heat pump development;
- Acoustic leak detection testing;
- In-situ piping heat loss measurement;
- Non-metallic piping development and testing;
- Mine water heat recovery heat exchanger testing; and
- Advanced thermal meter development.

The amount of funding required to adequately support R&D in advanced components for DHC systems in FY 1990 is $0.750m.

Innovative DHC Technology Program Opportunity Notice

In FY 1988 the DOE provided $0.250m in funding for five innovative DHC technology R&D projects which were proposed to the DOE in response to the DHC program's most recent program opportunity notice. One example of the type of projects proposed by private industry in response to this PON is the adaptation of a robotic in-situ pipe inspection and repair system which was initially developed at great expense by the Canadian nuclear power R&D program for inspection and repair of boiler tubing and other piping systems located in areas of nuclear power plants which have high levels of nuclear radiation. If this robot can be adapted for in-situ inspection and repair of buried DHC piping, the leaks, corrosion, lost insulation and other damage to which underground DHC piping is subject will be able to be remotely detected, precisely located and repaired. Currently, very inexact location and damage assessment methods are employed and all repairs must be effected by costly excavation. The cost advantages of the new robotic system over existing techniques could be as much as an order of magnitude, i.e. $20 to $200 per foot vs $200 to $2,000 per foot of pipe repaired.

Other projects proposed by private industry which will be supported in FY 1989 include the following:

- Build and test innovative prototype system for low cost installation of DHC piping in low density areas;
- Develop advanced heat transfer enhancement fluid for low temperature DHC system application;
- Develop heat activated desiccant cooling system as a means of utilizing low temperature district heat for cooling as well as heating;
- Develop design of three-pipe system for district heating and cooling systems; and
- Develop robotic in-situ DHC pipe inspection and repair system.

The DHC program's PON's have elicited a number of very promising technology R&D proposals in past funding rounds which have subsequently been commercialized. The projects currently being supported in FY 1989 exhibit good potential for success. However, there is already a backlog of promising projects which need additional support to get to the commercial stage. In the future, the PON should be directed to eliciting proposals from private industry in the area of advanced cogeneration as well as DHC technology. In order to enable the DHC program to minimally support the most promising efforts proposed in its FY 1990 PON it will be necessary to appropriate $0.750m for this purpose.

Advanced DHC System Technology Assessments

District heating and cooling is an energy supply system in the same sense as an electricity generation, transmission and distribution system or a natural gas transmission and distribution system. Thus, advanced DHC concepts and systems have to be studied in the context of the environment in which they will eventually have to operate before they can be commercialized. Since DHC systems are community energy supply systems they have to be assessed at the level of the community rather than within the confines of a single building as are most demand side energy efficiency technologies. In addition, since many of the more advanced DHC system concepts are predicated on supply by renewable energy sources which are relatively site specific, local assessments of the viability of DHC systems based on such sources are critical to determining the efficiency, economy and applicability of such systems.

For FY 1988 Congress appropriated $0.6m for such assessments which were to be focused on district cooling technology--an area which had not been the subject of study at the community level by any previous DOE program. Ten community district cooling technology assessments were selected for DOE funding based on responses to a DOE RFP. The communities selected by the DOE include the following: New Orleans, Louisiana; San Francisco, California; Honolulu, Hawaii; Phoenix, Arizona; New Haven, Connecticut; Miami, Florida; Little Rock, Arkansas; Baltimore, Maryland, Stamford, Connecticut; and St. Louis, Missouri. The projects selected focus on the assessment of new DHC technologies and their near term commercial application. Several of the projects are particularly worthy of mention.

The City of New Orleans, Louisiana will study a combination of advanced cogeneration and district cooling technologies which offer the potential to provide important solutions to both global warming and atmospheric ozone depletion problems. The system will consist of a natural gas fired diesel engine cogenerator (37% electrical efficiency); an electric chiller using ammonia rather than a CFC-based refrigerant with a coefficient of performance (COP) of 6.0; a double effect absorption chiller with a COP of 1.0 which converts the exhaust heat from the cogenerator into cooling and also does not employ CFC refrigerants; and a state of the art district cooling system. This combination of technologies is 38% to 63% more efficient than either average or state of the art individual building air conditioning systems and 48 to 70% more efficient than those same chillers after substitute "drop-in" non-CFC refrigerants are employed in place of CFC's.

If the New Orleans project is successful in an economic sense, it could prove to be the first of thousands of such systems implemented in communities throughout the U.S. The economic imperative of such a high efficiency system could well provide the economic incentive necessary to propel such technologies into the marketplace to accelerate the substitution of benign refrigerants for CFC's while at the same time reducing carbon dioxide emissions through the substitution of the much more energy efficient process of cogeneration for conventional central electric generation and single building electric chiller air conditioning which is presently virtually the only option available.

In Honolulu, Hawaii, another advanced district cooling assessment project is studying the use of cold ocean water to supply district cooling initially for Waikiki Beach and later for the entire city of Honolulu. This project will consider the feasibility of building an undersea pipeline several miles in length and 1400 feet below the surface to obtain cold seawater at about 42 degrees F which is available at that depth on a constant basis. This temperature is precisely the level required for district cooling.

A dense area of hotels around Waikiki Beach is the initial focus of the study which if successful could be extended to other dense commercial and residential areas of Honolulu. The proposed Honolulu Seawater District Cooling Project exhibits an 85% energy efficiency advantage over the competition--oil fired utility steam turbine power plants supplying electricity to single building chillers. Thus, this project has the potential to eliminate 85% of the carbon dioxide associated with energy consumption for air conditioning and 100% of the CFC refrigerants in areas where it is applied.

The project will provide a number of other benefits including access to air conditioning at relatively low, stable costs; substitution of locally available renewable energy sources for imported oil; and the achievement of a measure of energy security oil import dependent Hawaii. Furthermore, a number of American cities located along the Atlantic and Pacific coasts have similar opportunities to use cold seawater in direct or precooling district cooling applications. Thus, the Honolulu Seawater District Cooling Project could be the first of many such renewable district cooling systems.

In FY 1990 it is imperative that support for critical projects such as those described be continued and that additional projects are funded which similarly exhibit the potential for dramatic energy savings, carbon dioxide emissions reductions and substitution of benign refrigerants and renewable energy sources for CFC-based refrigeration. In future years it will be important to emphasize the assessment of advanced cogeneration technologies as well as DHC technologies. In order to accomplish these critical tasks a total of $0.750m will be required to support this program in FY 1990.

Environmental Impact Assessment of Advanced Cogeneration and DHC Technologies

In addition to the positive environmental impacts which advanced cogeneration and district heating and cooling technologies can have on the problems of global warming and ozone depletion, these technologies can also have a positive impact on other environmental problems such as local air pollution and acid rain. The ability of a source of pollution to employ the best available air pollution control technology is in large part a function of scale--the larger the facility the more available and the more cost effective the equipment will be. Conversely, such equipment is either unavailable or too costly to install and utilize in small individual building boilers.

However, central district heating production facilities are large enough to be able to cost effectively use the most advanced pollution controls and also to employ professional operation and maintenance personnel to ensure that both the plant energy conversion system and the air pollution controls are operating at peak performance levels at all times. Thus, through energy efficiency and the use of advanced pollution controls cogeneration/district heating systems can eliminate most of the uncontrolled stationary, building boiler sources of air pollution. Since no other effective means of mitigating these sources of pollution have yet been implemented in the United States it is particularly important to briefly examine a case in which cogeneration and district heating have effected a substantial improvement in the air quality of an urban area. The case in point is that of Stockholm, Sweden.

In 1965 when Stockholm was just beginning to build its district heating system the city emitted a total of 55,000 tons/year of sulphur dioxide emissions. Primarily as a result of the expansion of the district heating system and the substitution of high efficiency energy conversion systems including oil fired cogeneration using effective pollution controls for thousands of individual building oil fired boilers, the city reduced its sulphur dioxide emissions to 12,000 tons/year in 1985. Estimates of emissions of this pollutant in 1990 are 3,000 tons/year. Thus, a 95% reduction has been effected in 25 years. In addition, substantial reductions in the emission of heavy metals, dust and nitrous oxides have also been accomplished.

In addition to the general improvement in Stockholm's air quality which has resulted, the reduction in sulphur dioxide emissions has had a positive secondary impact in the form of a significant reduction in the acidity of the lakes around the city which have become highly acid over the years due to acid rain. Environmental studies concluded that local emissions of acid rain accounted for about 20% of the damage due to acid rain while the remaining 80% was attributable to "background" levels of sulphur dioxide produced elsewhere, i.e. in other parts of Sweden, England and the European continent.

Thus, it can be inferred that if similar measures were taken in places with similar energy supply, demand and environmental conditions that similar results might be expected. One area similar in many of these respects to the Sweden of 1965 is the northeastern United States. The potential for advanced cogeneration and district heating and cooling systems for significantly reducing the acidification of forests and lakes in the northeast needs to be explored in greater depth to determine if this option has the potential indicated by the experience of Stockholm.

Currently, the United States has embarked on a "Clean Coal" Technology R&D program which is primarily focused on the development of technologies which can achieve a substantial reduction in the sulphur dioxide emitted by large utility coal fired power stations located mostly in the midwest. The development and deployment of a new generation of cogeneration and district heating and cooling systems might prove to be a more cost effective long term solution than the retrofit option in not only reducing sulphur dioxide emissions to acceptable levels but also substantially cutting carbon dioxide emissions and improving the productive utilization of our energy and economic resources. The improved energy efficiency of cogeneration could accomplish this in cases where coal fired cogeneration and district cooling substitutes for coal fired electric power generation.

One coal fired cogeneration option which deserves attention is pressurized fluidized bed boiler technology. A potentially more attractive solution would be the use of methanol fueled diesel engine cogeneration systems in place of central coal fired steam turbines. Such substitutions would still enable coal to be used but would reduce emissions of both sulphur dioxide and carbon dioxide substantially. However, it will be necessary to study these options and the various tradeoffs in depth before the most viable solutions from the vantage points of economy, environmental quality and institutional acceptability are determined.

Although it is apparent that a number of advanced cogeneration and DHC technologies have substantial efficiency advantages over conventional electrical generation technologies, the precise environmental and economic impacts of the various tradeoffs have not yet been modeled on a regional level in the United States. A number of energy sources need to be assessed including natural gas, oil, methanol, urban waste and coal fired cogeneration.

Several different types of energy conversion systems need to be considered including diesel engines, otto cycle engines, steam turbines, gas turbines and combined cycles. A wide variety of renewable energy sources for supplying both district heating and cooling need to be considered including cold deep seawater, cold winter air for making ice for ice ponds and chilled water for aquifer storage; cool, dry nighttime desert skies for heat radiation/cooling production in the arid southwest; solar and wind energy for use in district heating; and a number of other promising renewable sources of district heating and cooling. Technologies will have to be considered on a regional basis and compared with both present and future competition in order to formulate economically and environmentally optimal mixes of cogeneration and DHC technologies for each region of the United States.

This task is a prerequisite for prioritizing numerous competing technology R&D projects in a way which ensures that those cogeneration and DHC technologies with the greatest potential environmental and economic impact are the ones which are given highest priority for future research and development funds. This effort will take three years to complete and will require $0.500m/yr. beginning in FY 1990.

Summary of Proposed DOE DHC R&D Program Budget for FY 1990

Subprogram	Proposed Funding FY 1990
Advanced Cogeneration and Heat-Activated Cooling Technology R&D	$1.0m
Advanced District Cooling Technology	1.0m
Advanced DHC System Components	0.750m
Innovative Cogeneration and DHC Tech. PON	0.750m
Advanced Cogeneration/DHC System Tech. Assessments	1.0m
Environmental Impact Assessment of Advanced Cogeneration and DHC Technologies	0.500m
Total Proposed DOE DHC Program Budget for FY 1990	5.0m

The International District Heating and Cooling Association is proposing over a five-fold increase in the DOE District Heating and Cooling Program budget for FY 1990 above the 0.9m level at which the program was funded in 1989. An increase of this magnitude is necessary because of the fact that the environmental problems which it is designed to surmount are so daunting.

If the United States is to meet the interrelated environmental challenges of global warming, atmospheric ozone depletion, acid rain and local air pollution it will have to make a substantial commitment of funding to develop those technologies which offer real potential for the resolution of these problems in the near future at costs and with methods which are acceptable. There are few if any energy supply technologies which can be readied in the short term to meet these challenges more effectively than advanced cogeneration and district heating and cooling technologies.

The proposed funding level of $5m/year is the minimum level necessary to mount a technology R&D program which is equal to the task. If the Congress is serious about discharging its responsibility for resolving the environmental crises facing the United States and the world it will take up this challenge by funding the DOE DHC Program at the $5m level in FY 1990.

APPENDIX 2: STATEMENTS FOR THE RECORD

MARCH 2, 1989

Alabama Power Company
600 North 18th Street
Post Office Box 2641
Birmingham, Alabama 35291
Telephone 205 250-1000

Alabama Power
the southern electric system

February 24, 1989

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research and Development
Committee on Science, Space and Technology
U. S. House of Representatives
Washington, D.C. 20515

Dear Congresswoman Lloyd,

Enclosed is my written statement which supports minimum funding of $39.8 million for the Department of Energies Photovoltaic Research & Development Program for Fiscal Year 1990.

I respectfully request that my statement be included in the record of the March 2 hearing.

Sincerely youre,

Herbert M. Boyd

Enclosures

cc: Subcommittee Members

STATEMENT OF HERBERT M. BOYD

Submitted to the
Subcommittee on Energy Research and Development
of the
House Committee on Science, Space and Technology

Madame Chairman, members of the Subcommittee, I am pleased to have this opportunity to present the views of the Alabama Power Company on the FY 1990 budget request for the Department of Energy's photovoltaic research and development programs.

I am Herbert M. Boyd, Director-Technology Management at Alabama Power Company, a subsidiary of The Southern Company.

First I want to thank the Chairman and members of the Subcommittee for supporting photovoltaic research and development by providing more appropriations than requested by the Department of Energy for each year since 1980.

The Department of Energy budget request for FY 1990 of $25.05 million for photovoltaic research and development is 29% lower than the $35.5 million appropriated for the current fiscal year. I fully realize that the administration's and Congress' goal for deficit reduction places severe limit on FY 1990 appropriations. However, the proposed $25.05 million is not adequate to carry on the minimum research and development programs that are essential for photovoltaic research during FY 1990. Congress recognized this by increasing the appropriations in 1989 to $35.5 million. The need for research has not changed since 1988 and foreign competitors have increased their efforts.

The world photovoltaic markets, of which the U.S. once held an 80% share, are expected to grown into a $1 billion a year market by the year 2000. America's market share has fallen to 31% as our R&D expenditures have fallen behind those of Japan and Germany whose R&D expenditures and market shares have risen. If we support research in these technologies, we can develop and sell them to the world; if we don't, then we will buy them from others. The photovoltaic industry can have a significant positive effect on our technological competitiveness and our balance of payments. Now is the time to support the industry and to reemphasize R&D.

The electric utility industry will be seeking new sources of energy by the mid-1990s and renewable energy technologies should be available for consideration at that time to help meet the United States' energy independence goal. We believe that one of the renewable energy technologies that offers great promise as a source of clean energy for the utility industry is photovoltaics. This belief is demonstrated by Alabama Power Company building and placing into operation the world's largest amorphous silicon thin-film photovoltaic grid connected array. This 75KW demonstration unit is now producing enough power at the time of our system peak to supply the energy for 19 homes.

In addition to the $1 million spent on the above installation, Southern Investment Group, another subsidiary of The Southern Company, has invested $6.1 million in a joint venture with Chronar Corporation to build and put into operation a 1MW amorphous silicon photovoltaic cell manufacturing facility in Birmingham, Alabama.

The Department of Energy research programs have enabled the domestic photovoltaic industry to make steady progress in developing a clean, competitive energy supply alternative. Today photovoltaics are competitive with other energy sources at remote sites. The Coast Guard has installed more than 9,000 photovoltaic aids to navigation worldwide that will save an estimated $2 million per year in maintenance costs and between $2 and $3 million per year in battery costs. However, even though many advances have been made, there is still important research needed to further increase conversion efficiencies, improve reliability and reduce costs in order for photovoltaics to be a viable energy source for central power applications.

The United States is in a race with Japan, West Germany and other countries in the development of photovoltaics for central power applications by utilities. The winner of this race with the best technology and lowest cost will have a worldwide market for their products. The U.S. utility industry does not want to import the photovoltaic products needed to meet the energy demands of the 1990s.

However, as the Department of Energy appropriation for photovoltaics fell from $153.2 million in FY 1981 to $35.5 million for FY 1989, research and development funding in Japan, West Germany and other countries has been increasing. For example, Japan has increased funding for photovoltaic programs from less than $5 million in 1980 to $53 million in 1988. Included in this are expenditures for amorphous silicon research and development, which have increased from $2 million in 1980 to $23 million in 1988. During the same period, expenditures for amorphous silicon research and development increased from $5 million in 1980 to $10 million in 1987 but fell to only $8 million in 1988. If we adopt the current budget, Italy will spend more for photovoltaic research and development in FY 1990 than the DOE.

Since 1981 amorphous silicon thin-film photovoltaics have increased from 3% of total photovoltaic world sales of 5MW to above 40% of the total market of 34MW in 1988. We believe that amorphous thin-films offer potential for power applications in the utility industry and is the photovoltaic technology we are currently investigating. During the past year, with help from Department of Energy funding, efficiencies of more than 14% have been achieved with new thin-film materials. However, as methods are found to increase efficiencies in the laboratory, additional research and funds are needed to use these new materials in low-cost, reliable, large area submodules. This work needs to be done in the United States and not in Japan and West Germany.

The Southern Electric System continues to feel that fundamental materials research will eventually advance the photovoltaic state-of-the-art further than any of the other areas of current investigation. Until the industry can understand why materials behave as they do, solutions can not be theorized or developed to solve manufacturing problems associated with thin-film photovoltaic cells. Since cost is a significant driver in all manufactured products, basic materials research is needed to make these improvements in structure as well as manufacturing. In addition, the industry must strive to develop new materials which have the capability of increasing efficiency so that the cost goals required to be competitive with existing energy forms can be achieved. My recommendations for FY 1990 is as follows:

ACTIVITY	DOLLARS IN THOUSANDS
Advanced Thin Film Materials	$15,500
High Efficiency Materials	8,200
Fundamental Materials Research	13,500
Collector Research	800
System Research	1,400
Capital Equipment	400
TOTAL	$39,800

As you can see, this exceeds the 1989 appropriation of $35.5 million. However, if we as a nation are to stay competitive with other countries, then the level identified above is a minimum for advancing the necessary photovoltaic technologies.

American Wind Energy Association

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TESTIMONY OF
Thomas O. Gray
Executive Director
American Wind Energy Association

on the U.S. Department of Energy Authorizations
for Wind Energy Research and Development

Before

THE HOUSE SCIENCE, SPACE, AND TECHNOLOGY COMMITTEE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

March 2, 1989
Washington, D.C.

1730 N. Lynn Street, Suite 610, Arlington, VA 22209 USA Tel. (703) 276-8334 Telex 6503304640 MCI UW

1. Introduction

The American Wind Energy Association (AWEA) is a trade association which represents wind turbine manufacturers, component suppliers, developers, electric utilities, and other companies around the nation. About 150 corporations are members of AWEA.

Wind energy is working today -- our industry generated about 1.8 billion kilowatt hours of electricity in 1988. Wind energy is also clean -- our industry can help alleviate air pollution problems around the nation.

2. Summary of Testimony

In the last nine years, the U.S. Department of Energy (DOE) budget for wind energy research and development has decreased to the point where appropriations are now a small fraction of what they were in 1981. These reductions have harmed the industry, and AWEA is seeking to reverse this trend. Specifically, we seek appropriation levels in fiscal 1990 of $10.8 million. This sum includes funds to design and build several prototype advanced wind turbines that will allow our industry to meet the domestic and international challenges of the 1990s.

3. Status of the Wind Energy Industry

There are now about 16,000 commercial wind turbines in the United States. About 90 percent of these machines are in three locations in California. In total, the wind turbines there have an installed capacity of about 1,500 megawatts. In 1988, these turbines generated approximately 1.8 billion kilowatt hours of electricity, enough to meet the annual residential needs of Washington, D.C.

4. Historical Overview of the Federal R&D Budget.

In the 1970s, after the OPEC oil embargo, the DOE initiated an ambitious research and development program in wind energy that put the United States -- its national laboratories and industry -- in the international vanguard of wind technology. In the 1980s, however, these budget levels were reduced sharply.

We are now at the point where fiscal 1989 appropriations are approximately one-tenth of what they were in fiscal 1981. The figures on the next page document the decrease in federal R&D funds for wind.

Federal Appropriations for Wind

Fiscal	1981:	$83.7 million
	1982	34.7 million
	1983:	31.4 million
	1984:	26.5 million
	1985:	29.1 million
	1986:	24.8 million
	1987:	16.7 million
	1988:	8.6 million
	1989:	8.8 million

The proposed fiscal 1990 budget calls for appropriation levels of $8.35 million, yet another reduction.

These reductions, coming on the heels of the removal in 1985 of federal tax incentives for private investments in commercial wind energy systems, have seriously damaged the U.S. industry's ability to compete in the domestic and international arena. AWEA believes a budget increase is necessary for the industry to regain its leadership in the increasingly competitive international marketplace.

Specifically, AWEA requests an appropriation of approximately $10.8 million in fiscal 1990. The additional funds ($2 million above 1989 appropriations) would be allocated for the design and construction of several prototype advanced wind turbines.

5. The Role of the Federal Research and Development Program

The DOE budget for wind energy performs a vital function: the department and the national laboratories conduct technical and economic studies that are on the forefront of aerodynamics, structural dynamics, advanced components and other supporting research. From these studies the commercial industry obtains a better understanding of loads imposed on a machine and the designs needed to build more cost-effective and reliable turbines.

6. Why Additional Funds Are Needed

AWEA is requesting that Congress appropriate $10.8 million in fiscal 1990 and that this increase over 1989 appropriations be earmarked for the advanced wind turbine project.

The advanced wind turbine would be in the intermediate size (200-500 kW) and would incorporate major advances in turbine design and operation.

The wind turbine would offer three distinct advantages: 1) it would operate economically in lower wind speeds; 2) it would generate electricity at a cost of about 5 cents per kilowatt hour, compared with current costs of 7-9 cents per kWh; 3) it would be larger than most commercial machines on the market and would be more reliable, thus reducing overall lifecycle costs.

A turbine of this size and design would be optimal for utility development. If commercialized, AWEA expects that several electric utilities in the country would invest as equity owners in a machine of this type.

7. The Joint Venture R&D

AWEA is also a strong supporter of H.R. 1216, the three-year authorization bill for renewable energy. The bill contains language that would allow the Secretary of Energy to form joint venture research and development projects in renewable energy with the private sector.

We believe the joint venture approach would allow the federal government to develop the advanced wind turbine in cooperation with leading private firms in the United States.

8. International Competitiveness

In the last nine years, while the U.S. cut its federal R&D budget, the European countries have been increasing their research efforts in this field. Danish and Japanese firms have entered the U.S. marketplace in recent years with newer and larger machines. If this trend continues, the U.S. is in serious danger of loosing the competitive advantage it has held to foreign firms, many of them supported by their national governments.

9. Conclusion

AWEA urges Congress to halt the nine-year decline in federal R&D fund for wind energy.

Our industry cannot remain competitive if the U.S. government does not support wind technology with stable funding. We need a sufficient level of funding that allows us to learn from past experience and to build a new generation of wind turbine that can tap the immense but untapped wind resources of this country and other parts of the world. In recent years, we have seen our technology and jobs go overseas. Fair and realistic appropriation levels for the wind energy program will help reverse this trend.

IEEE

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Promoting Career and Technology Policy Interests of Electrical, Electronics & Computer Engineers

April 3, 1989

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The Honorable Marilyn Lloyd
Chairwoman,
Subcommittee on Energy Research and
Development
House Committee on Science, Space and
Technology
Room B-374 Rayburn House Office Building
Washington, DC 20515

Dear Congresswoman Lloyd:

Enclosed for your hearing record is the statement of the Institute of Electrical and Electronics Engineers, Inc., on the Fiscal Year 1990 budget for the Department of Energy's Electric Energy Systems and and Energy Storage programs. Should you have any further questions regarding our perspectives on these programs, we would be more than happy to provide you with additional supportive information.

Thank you for the opportunity to provide our views on these important research efforts.

Sincerely,

William R. Tackaberry,
Chairman,
USA Technology Activities
Council

Enclosure

IEEE-USA, 1111 - 19th Street, N.W. Suite 608, Washington, DC 20036-3690

The Institute of Electrical and Electronics Engineers, Inc.

STATEMENT TO THE HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
by the
U.S.A. Energy Committee
of the
INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.,
on the
ELECTRIC ENERGY SYSTEMS AND ENERGY STORAGE SYSTEMS
RESEARCH PROGRAMS OF THE
U.S. DEPARTMENT OF ENERGY
April 3, 1989

The IEEE-USA Federal Legislative Agenda for the 101st Congress states:

> "Energy is important to the nation's economic growth, national security, and international competitiveness. Although the public is generally optimistic about energy supply, the United States must take steps to ensure continued access to reliable, low-cost, environmentally acceptable Energy."

On Electric Systems, the Agenda states:

> "Reliable, affordable and environmentally attractive sources of energy are vital to this nation's economy and to international competitiveness. Equally vital is the use of electricity as a means of distributing energy. Electricity is extremely flexible. It can derive energy from a variety of sources and distribute it to a variety of applications. For these reasons, research in electrical systems is essential to an adequate energy supply. Further, current regulatory efforts to restructure the electric utility industry are raising critical system reliability issues. The United States needs to understand the implications of these issues so it can avoid unnecessary disruptions in electric power production. The nation should consider engineering expertise and economic factors equally in these efforts."

We feel that the DOE Office of Energy Storage and Distribution is a vital partner in ensuring the competitiveness of our industries by supporting research and education on electric power systems that are not adequately covered by the private sector or other government-supported programs.

The IEEE-USA strongly supports this mission and there is no doubt that the Electric Energy Systems (EES) and Energy Storage Systems (ESS) programs fill an essential role in supporting the nation's science and technology base.

In the DOE FY 1990 budget overview for EES, DOE requests funding of $16.8 million for EES research and $8.1 million for ESS to achieve its stated mission, a total of $24.9 million. This is a reduction of 30% from the FY 1989 budget of $36.3 million. In reviewing the history of the EES and ESS budget authority, one finds that this has decreased from about $90 million in FY 1981 to a low of under $30 million per year in FY 1986, FY 1987, and FY 1988.

Electric Energy Systems

In a 1986 report on the DOE Electric Energy Systems program, the National Research Council - Committee on Electric Energy Systems recommended:

> "...that the EES program be supported by a budget of approximately $45 million annually."

However, the support for the EES research activities has been severely decreased over the last few years and this declining trend is continuing in the FY 1990 DOE Budget Request with a reduction of 27% below the FY 1989 appropriation. In addition to the general decline, the FY 1990 budget request also indicated a continuing decrease of the support for discretionary R&D in the EES program.

In FY 1989, more than 75% of the total EES budget appropriation was in two research areas; namely, the Hawaiian Deep Water Cable and high temperature superconductivity. In FY 1990, 72% ($12.122 million) of the DOE request for EES is for high temperature superconductivity. This appears to be a major restructuring of the EES program from earlier years, and leaves only $5 million to cover the other important research areas in the OESD mission for EES such as Electric Field Effects, Reliability R&D, and Materials Research (other than high temperature superconductivity). Therefore, we strongly advise that increases in these categories of the EES budget should be made while maintaining the superconductivity research funding at the $12 million level.

In the Electric Field Effects element of the EES program, the requested budget is $2.2 million and is $800,000 less than that appropriated in FY 1989. This amount is significantly inadequate at a time when there is increasing public concern about health effects from electric and magnetic fields from all forms of electrical energy delivery and utilization.

Without intensive research to determine the extent and nature of electric and magnetic field interaction with biological systems, the most useful and convenient form of energy may be unnecessarily constrained. However, if serious interactions are found, then the thrust of the whole DOE program may need to be reexamined.

In a review of the DOE-EES research effort on power system electric and magnetic field effects by the National Research Council in 1985, the Review Committee recommended a level of $12 million, stating that:

> "the EES program [needs to] considerably upgrade its efforts as a neutral sponsor of research in this controversial area."

The IEEE strongly urges Congress to begin to move this research towards adequate funding. We have appended a copy of the recently approved IEEE Entity Position Statement on "Biological Effects of Power-Frequency Electric and Magnetic Fields" to support further the need for a stronger DOE research role in this field.

Reliability Research and Development is proposed to be cut by 27% from last year's appropriation. If the level of support is sustained by Congress, this will severely impact important research activities designed to (1) enhance the knowledge of large scale automation of the distribution and transmission system for system reliability, load regulation, and energy conservation and enhance the knowledge of the factors causing deterioration in the power quality; (2) develop options on control and operation strategies for a potentially deregulated future electric utility system currently being explored under FERC proposals; and (3) develop detection and recongnition strategies for large scale system instabilities caused by inter-regional power transfers.

The North American Electric Reliability Council (NERC) annual report for 1986 states:

> "Now, in 1987, we find ourselves faced with new challenges. The number of electric service interruptions seems to be on an upward trend. Utilities are being challenged by non-utility generation, the effects of large fluctuations of energy prices, increasing competition for customers by other utilities, and by other countries vying for our industries. Finally, we are being challenged by regulations that many think are usurping management control of planning and operations. Overall, the value and importance of reliability is being overshadowed by a concern for the price of electricity."

This element also includes the study of Electromagnetic Pulse effects on the nation's power grid from high altitude nuclear detonations. The North American Electric Reliability Council (NERC) in their 1986 Annual Report states:

> "the biggest immediate problem is the lack of funds needed to bring the DOE research [on EMP] to a timely conclusion. We have spoken to many officials throughout the industry and within government on the importance of promptly completing this research."

The IEEE fully supports this statement.

We feel that these issues are important national concerns and the national issues are constanly changing. Increased interruptions, regulatory issues, capacity constraints, transmission bottlenecks, and environmental concerns are constantly challenging the utilities. It is important that scientific breakthroughs and new technologies are quickly brought to bear on the solutions to these and other issues. These solutions include new transmission and distribution options, such as use of high phase order (6-phase and 12-phase) transmission lines and supercomputers in real and near-real time analysis of large interconnected power systems for stability and load flows. We strongly recommend that the Reliability Research be funded at least at $3.5 million and be put on a path of increasing yearly funding.

The Material Research activity request for over $12 million is strongly supported by the IEEE. However, we view with alarm that this is exclusively for superconductivity research. Materials are the building blocks of all devices used in the industry. Without access to the best, most cost-effective materials and processes in the United States, the U.S. supply industry cannot remain competitive. Therefore, a sound fundamental research program in materials and technology base support is needed to lead to innovations in utilization of materials in equipment.

Such a necessary broad-based approach is now in danger of being curtailed. A balanced approach is needed in the materials research. As was clearly demonstrated with the discovery of the new high temperature superconductors, the area of scientific breakthrough is hard to predict but clearly depends upon a solid broad-based foundation of both basic and applied research. We urge you to go beyond the request of $12 million by adding at least $2 million for other materials research.

There is clearly a need also for research well beyond development of new materials and the understanding of material degradation and failure phenomena. The incorporation of materials into devices requires the evaluation of new materials and devices on systems operations and the development of new technological systems. It is therefore alarming to note that the Systems Research element of the EES program has been proposed for zero funds. This element has in the past years carried the majority of the EES portfolio for applied research and technology development including R&D on low temperature superconducting cables and generators and high voltage direct current transmission. Important research on these and other important alternative transmision technologies and electric power component R&D has already been curtailed over the last years from lack of support. This has taken place at a time when regions of the nation are facing a shortfall in electric generating capacity, aging electric generation equipment and transmission facilities, and when the existing transmission system is being operated up to its limit.

This situation is particularly alarming when U.S. utility equipment industry no longer can supply the full range of power equipment needs. Transmission cables, advanced power semiconductors, circuit breakers, large motors, and transformers are but a few of the vital utility equipment areas being abandoned by U.S. industries or receiving diminishing R&D funds. The U.S. electric equipment manufacturers are now directing almost all their R&D effort on existing electric power equipment product improvements in order to meet foreign competition within a short time horizon. However, technology development and expertise important to the continued operation and security of the electric utility system are now in danger of being left out. Research and development in industry, universities, and national laboratories should therefore be supported in these areas in order to develop and maintain the technically informed manpower needed by the utility industry. The support of consortia and research centers is an effective way for the federal government to leverage funds and provide assistance to new fields of research and development. We strongly urge you to support this situation by providing at least $4 million for Systems Research.

The EES program therefore provides an important alternative and addition to the market-driven R&D in the United States today and provides an alternative source for funds to university research not supported by, for example, the National Science Foundation. In order to meet the future needs for manpower in power engineering, we propose that the funds should be provided for the EES program to set up five graduate fellowship programs for support of U.S. students, each for $25,000 per year for four years. This will be a strong attraction to potential U.S. Ph.D students.

Energy Storage

Improved Energy Storage technologies enable greater efficiency and flexibility for the nation's energy system. Storage technologies are required both as an independent technology such as for utility load leveling to provide peak power at competitive cost without the requirement of new base load generating capacity and as an enabling technology to improve the economics of intermittent renewable energy systems or for effective storage batteries for electric vehicles. Successful development of a range of energy storage options can provide answers to several national problems including projected regional electricity capacity shortfalls, concern over environmental improvements, reduction of oil imports, and restoration of U.S. industrial competitiveness.

The Department of Energy's support for the development of energy storage technologies has eroded from more than $50 million in 1981 to only $13 million in 1989. No other DOE research program has been subjected to these deep budget cuts and the FY 1990 budget requests only $8.1 million - a proposed cut of almost 40%. The need to support energy storage has never been greater as their successful development can be a key aspect to the resolution of many energy related issues.

Many scientific, engineering, and policy bodies including the National Research Council, Energy Research Advisory Board, The Electrochemical Society, American Society for Mechanical Engineers and the Institute for Electical and Electronics Engineers have reports or positions supporting enhanced budgets for these technologies. They recognize the failed policy of the previous administration to leave the responsibility solely to industry. The risks are too high for industry to "go it alone" but the rewards are too great for the U.S. to ignore.

With this in mind we recommend increased support for the following research efforts:

- Electrochemical Research - to better understand the underlying concepts to develop storage batteries for electric propulsion and storage of electricity. Additionally, to train a diminishing supply of electrochemists at U.S. universities so that we can capitalize on the projected multi-markets identified for future opportunities in electrochemistry. A minimum stable program of $7.5 million is required to perform this ongoing critical research function.

- Battery Development - the development of advanced battery technologies, such as the sodium-sulfur and zinc-bromine technologies, can resolve problems related to electricity shortage; promote the use of renewable energy, and provide environmental solution for acid rain and the greenhouse effect. We are in a race with Japan and Europe to develop these batteries for electric vehicles and electric utility load-leveling with the winner able to capture a market estimated as high as $20 billion. Budget cutbacks have not allowed for DOE to perform any battery engineering for these systems. We recommend a sustained commitment of $10 million for ten years to have batteries ready for use in regional capacity shortages before the year 2000.

- Fuel Cells for Transportation - the proton exchange membrane (PEM) fuel cell has undergone tremendous breakthrough in both performance and cost reduction in the laboratory the last two years. The advent of a high power fuel cell for vehicles would provide us the option of shifting our reliance on imported oil to domestic sources such as methanol. We recommend $6 million per year so that DOE can pursue cooperative development of PEM fuel cells and develop a direct methanol electro-oxidation fuel cell.

- Thermal Storage - is an option to improve efficiency where there is a mismatch in energy supply and demand, such as commercial building air conditioning, space heating, or industrial process. Thermal storage can positively impact electric supply problems by reducing demand, and encourage the use of solar energy in commercial and residential buildings. We recommend a continued and sustained effort at $5 million per year to pursue these technologies.

- Superconducting Magnetic Energy Storage (SMES) Program is the only known technology for the bulk storage of energy directly as electricity. SMES stores electric energy as DC electric current passing through an inductor. SMES exhibits very high energy storage efficiencies: round-trip AC-DC-AC efficiencies of about 90% are typical. The system responds to a load change more rapidly (<1 sec) than any other energy storage system. SMES is, in principal, nearly ideally suited for electric utility load leveling applications. However, two major problems confront the implementation of SMES units: the high cost of SMES, and environmental issues associated with the strong magnetic field. Projected costs for a 1-GW SMES unit are >$1300/kW, in 1982 dollars. The recent major advances in superconductivity technology could have a major impact on SMES costs, provided that they can be made into appropriate shapes and withstand high current fluxes. We recommend an effort at the $2 million per year to pursue this technology.

The United States must reaffirm its investment in energy storage as part of a mitigation strategy for previously cited national problems. Ignoring this investment would be short-sighted and result in pursuing these technologies offshore in the near future.

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